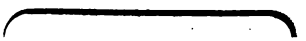

A

SYNOPSIS

OF

LECTURES ON GEOLOGY,

COMPRISING THE

PRINCIPLES OF THE SCIENCE.

DESIGNED

AS A

TEXT BOOK.

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PREFACE.

To encourage a taste for the highly interesting and *moral* science of Geology, to elicit a spirit of investigation and afford assistance to those who are desirous of obtaining a knowledge of its principles, which can no longer be neglected with safety to revelation and morals, is the design of the author in the following pages. The work contains the substance of courses of lectures delivered to several classes in the County of Bristol, Mass., and in Rhode Island, in 1834-5.

The want of a suitable book, of a moderate size, as a companion, or *vade mecum*, during the delivery of the lectures was seriously felt, by the members of the different classes. The technical terms being new to most of the audience, were not readily comprehended, although much pains was taken to render them familiar by *specimens and diagrams*; it occurred to the lecturer and to others that if a small work could be prepared to which every one might have access, during the lecture, it would greatly facilitate their progress, and, also aid in their future investigations.

Geological works are, in general, voluminous and scarce, and the expense such, as not to comport with the means, or inclination of many who are desirous of obtaining some knowledge of this useful branch of science, hitherto almost *novel* in this part of the country. And very few of these are calculated for *text books*, in a popular course of lectures.

In compliance with the request of many of the members of his classes, the author has here given a *synopsis* of his lectures according to the latest and general acknowledged theory of the formation of the earth. Which he believes will not only prove use-

ful as an auxiliary to those attending lectures, but as a book of reference to others.

In the compilation, he has consulted the works of the most eminent Geologists of Europe and America. Among others, those of McCulloch, Ure, Conybeare and Philips, de la Beche, Cuvier, Humboldt, Parkinson, Bakewell, Hitchcock, Eaton, &c.

No pretensions are made to infallibility, or that the work is unexceptionable; such pretensions would be falacious in the present state of the science. There is not any science so incumbered with various and conflicting theories as Geology, but it appears approximating to a permanency. Great and powerful minds are employed on the subject; analysis and rigid induction are called to its aid; investigation is pursued with zealous and untiring industry; a desire and taste for its pursuit pervades all classes, and we may hope that its correct principles will soon be established on as permanent a basis, as those of Astronomy and Chemistry.

If this brief manual shall, in any manner contribute to promote the interest of science, or gratify the wishes of his friends, the author will feel himself amply rewarded. For many imperfections, he claims indulgence, hoping that they will not be found of such importance as to render the wish too presumptuous of having it considered as a humble subsidiary to scientific and valuable comprehensive works.

J. R. C.

Taunton, August, 1835.

LECTURE I.

DEFINITIONS &c.

GEOLOGY literally signifies a discourse concerning the earth. Its formation, strata, mountains, valleys; the remains of organized beings found in its solid contents &c. the probable antiquity of the earth; and the causes which have formerly, or are still operating to produce the changes which we witness on its surface, or beneath its crust.

Oryctology is the science which treats of the nature, origin and formation of those bodies which possess the figures, markings or structure of vegetables, or animals; whilst the substance evinces their having been preserved through many ages, by certain changes effected in subaqueous, or subterranean situations. The substance of which they are composed being generally of a mineral nature, the term *fossils* is applied to them as indicative of their having been *dug* from subterraneous situations.

The earth was created by an intelligent and Almighty being; laws or principles were infused and the changes were produced by the efficiency of those laws operating by His agency.

The earth is a spheroid, this appears to be the

effect of rotation, or such a figure as a fluid body would assume if revolving in space. Its equatorial diameter, 7924 miles nearly ; Its polar axis 7898. Difference—26 miles.

Mean density of the earth 5. nearly, or about five times heavier than a globe of water of equal bulk.

The relative proportion of dry land, at present, is to that of water as 2-5ths to 3-5ths ; but there is but about 1-5th habitable by man.

A central heat appears probably to exist in the earth, which is an important agent in supporting the present temperature of the globe. This hypothesis receives confirmation from the occurrence of numerous active and extinct volcanoes ; from rocks which are evidently of igneous origin, and from hot and warm springs, as well as from observations made in mines, that the temperature increases as we descend. But decreases from the surface until we arrive at the termination of solar heat, when it begins to increase.

The superficial contents of the earth are calculated at 190,000,000 square miles.

The following are the different classes of rocks.

1. Primary, or the lowest, containing no fossil organic remains.

2. Transition, containing organic remains of the lowest class of animals and vegetables ; also fragmentary rock, of the primary class.

3. Secondary, lower and upper.

The lower distinctly stratified, composed of sand stone, beds of coal, and iron stone and the fossil remains of vegetables.

The upper series of secondary strata contain stratified limestone with beds of shale and sand stone interposed, and the fossil remains of marine animals, but different from those in the lower. Here we find the remains of animals of the lizard species of immense size. Also, the bones of fresh water and amphibious reptiles.

These strata appear to have been formed under different circumstances from the lower, but after a long interval of time when the surface of the globe had been much fractured and displaced. They do not lie parrallel with the lower, but are *unconformable* and cover the edges of the lower.

4. Tertiary, or the most recent formation.

In these strata are numerous bones of quadrupeds of the class mammalia, of terrestrial origin, the greater part of which appear to belong to genera and species no longer living in any part of the globe. Also numerous marine and fresh water shells, the latter appear to be more numerous than the former.

Basaltic and volcanic rocks. Or those which have either been ejected from volcanoes, or emitted in a state of fusion from rents and openings through the crust of the earth. Sometimes they occur in a columnar form, and sometimes they fill vast fissures, or dykes.

Diluvial and Alluvial.

The first consists of vast beds of gravel, fragments of rocks, and boulders hurled to great distances from their original beds. Also siliceous sand and disintegrated rocks, assuming a stratifi-

ed structure. The second consists of sand, pebbles, pieces of wood, leaves &c; also the bones of animals, and decomposed animal and vegetable substances.

These classes have their appropriate mineral contents, which serve as data to our observations and the epochs of their formation.

LECTURE II.

Of the mineral substances composing the crust of the globe

The mineral substances that occur in the surface of the globe differ in density, hardness, color and other properties. All the variety of rocks, however diversified are composed of a very small number of simple substances.

The elementary substances of which the solid matter of the globe is composed, are, in general, the following.

Silex, Allumine, Lime, Magnesia, Iron, Manganese, Carbon, Sulphur, Potash, Soda, Muriatic, Carbonic, Sulphuric and Phosphoric acids. Also in a very limited proportion, Strontian, Barytes, Glucina, Zirconia and, Yttria, as well as metallic

ores, but the proportion is so small as not to merit notice.

Silex, or siliceous earth, exists nearly pure in quartz rock, and rock crystal. It communicates a degree of hardness and grittiness to all rocks into which it enters in any considerable degree. It composes more than one half of the solid matter of the crust of the globe. In some hot springs, silex occurs in the state of minute division, or in solution. As in the Geysers of Iceland.

Alumine, or pure Clay, this in a mixed state is well known, but unmixed it is very rare. It is soft, smooth, unctuous to the touch; very absorbant of water; rocks containing it in the proportion of 30 per cent, or more are called argillaceous. Iron appears to have a greater affinity for this earth than for any other. Few clays are destitute of a portion of iron. It forms a principal constituent part of most stones, and of extensive strata.

Lime, combined with carbonic acid forms lime stone, marble, chalk &c. Stones containing it are called *calcareous*. United with sulphuric acid, it forms gypsum, or Plaster of Paris, with fluoric acid, Derbyshire Spar. Marl is a composition of lime and clay, with a small portion of silex. Limestone generally effervesces with acids.

Magnesia, rarely pure in nature, but in composition it communicates a soapy feel to the rock, sometimes, a striated or striped texture and the property of resisting high degrees of temperature. It occurs in limestone in different proportions. It abounds in talc and soap stone.

Iron, is very abundant in the mineral kingdom, it forms a constituent part of various rocks and stones, and imparts different colors. It is combined in the state of an oxide, or a metal. In composition, it increases the specific gravity of the mineral. It gives a tendency to decomposition of the rock in which it enters, especially when combined with sulphur.

Manganese, This in the state of an oxide communicates a dull reddish color inclining to purple, and a peculiar dry and burnt like appearance. It occurs only in a few rocks.

Sulphur, combined with oxygen, forming sulphuric acid, enters into the substance of some rocks, such, as gypsum, though its combinations are not extensive. It combines with iron and forms the well known substance of a crystalline form and yellow color, called *sulphuret of iron*, or iron pyrites. Often mistaken by the inexperienced for gold.

Carbon, enters into the composition of many of the slate rocks, to which it imparts a dark color; it also forms the principal constituent of coal. When combined with oxygen it becomes aeriform and is carbonic acid, or fixed air, in this state, it is solidified in all limestone rocks, forming nearly 2-5ths of their weight. It is regarded as a constituent element, and not derived from the vegetable kingdom.

Potash and Soda, these alkalies occur in some minerals, but in a very small proportion. Soda occurs abundantly in sea water. Pure rock salt, or sea salt contains about 53 1-2 per cent of Soda, 46 1-2 muriatic acid, or chlorine.

Muriatic acid, combined with Soda, is the only state in which it is found in rocks; except in some volcanic rocks; composition of muriatic acid, hydrogen and chlorine.

Phosphoric acid, is found in a few secondary limestone beds, perhaps obtained from the decomposition of animal bones.

The following simple minerals form what is denominoted the alphabet of Geology, because, by means of them, we are able to *spell out*, or determine all the rocks of the globe,

Quartz, Feldspar, Mica, Talc, Chlorite, Hornblende, Gypsum, Limestone and Argillite.

Quartz, color various, hard and brittle, gives sparks with steal; fracture of the crystallized conchoidal; uncrystallized splintery; lustre vitreous, resembling a piece of polished cold tallow. Occurs massive, crystallized, and granular, common form of the crystals, six sided prisms terminated by six sided pyramids, transparent; uncrystallized, opaque or translucent, sp. gr. 2. 53, composed of silex and a small proportion of alumine. Infusible by itself, not acted upon by any acid except the fluoric. It exists in veins and in large masses forming mountains. Fragments or crystals common in compound rocks. Grains of quartz form the principal constituent of sandstone. It forms the principal constituent of flint, hornestone, chalcedony, opal, agate &c. when in combination with a large portion of alumine, Jaspar.

Feldspar, is a constituent part of numerous

rocks, less hard than quartz, frangible, laminar or composed of thin plates, which may distinguish it from quartz, crystallized in four and six sided prisms, whose length is greater than the breadth; lustre shining, resembling the broken edge of a china cup; colors, white, grey, red, reddish white and green. Translucent, or opaque, melts without the addition of an alkali, sp. gr. 2. 54. comp. silex 63. 17, alumine 17. 14, potash 13. lime 3. 6, oxide of iron 1. Its fusibility is owing to the potash in its composition.

It constitutes the principal constituent of most rocks and light colored lavas.

Mica, from *micans* glittering, commonly called *Isinglass*, or muscovy glass. Occurs in leaves, or lamina, elastic, transparent; colors yellow, grey, blackish, brown, white, green; yields to the knife, crystallized into six sided tables, or six sided rhomboidal prisms, melts into an enamel; sp. gr. about 2. 7.

Composition, silex 48. alumine 34. 35, potash 8. 73, oxide of iron 4. 5, manganese 0. 5, water 1. 25.

Talc, nearly resembles mica in appearance. Flexible, but not elastic, softer than mica, infusible. Color silvery white, or green, has a soapy feel, yields to the nail; lustre shining pearly; sp. gr. 2. 79.

Comp. silex 61. magnesia 30. 5, potash 2. 75, oxide of iron 2. 5, water 0. 5.

Chlorite, nearly resembles talc, it is of a green color, whence its name; lustre glistening; structure minutely foliated; soft and rather unctuous,

sp. gr. from 2. 6 to 2. 9. Silex 26. magnesia 8. alumine 18. 6, oxide of iron 43, muriate of soda and Potash 2. 0, water 2.

Hornblende, Fr. amphibole, color black, or dark bottle green, heavier but less hard than quartz, or feldspar; it may be scratched with a knife, color of the streak light green, yields a bitter smell when breathed on; melts easily into a black glass, occurs massive and crystallized. Sp. gr. 3. 15, to 3. 30.

Composition. Silex 47. 21, alumine 13. 94; lime 12. 73, magnesia 21. 86, Oxide of iron 2. 28; oxide of manganese 0. 56; fluoric acid 0. 90; water 0. 44.

Gypsum or *sulphate of lime*, color white, snow white, and reddish. Structure laminated, granular, crystalized or compact, yields to the nail; does not effervesce with acids. Crystalized gypsum is called selenite. Sp. gr. 2. 16, to 2. 28. Composition. Lime 32. 7, sulphuric acid 16. 3, water 21. That variety which has no water in its composition is called *anhydrous*.

Limestone, color white, yellow, brown, reddish, black, grey, greenish and blue, effervesces with acids, yields to the knife, infusible, sp. gr. 2. 6. Composition. Lime 57. Carbonic acid 43. Magnesian limestone is sometimes called *Dolomite*.

Argillite, color bluish, or greenish grey, lustre silky, yields to the knife; emits an argillacous odour when breathed on; roof slate and cyphering slate afford good examples of argillite. Sp. gr. 2. 5. Composition. Silex, 48; alumine 25. 5, magnesia 1. 6; oxide of iron 11. 3; oxide

of manganese 0. 5; potash 4. 7; carbon 0. 3; water 7. 6.

LECTURE III.

On Stratification.

Stratum signifies a bed, and in geology, it is applied to a bed of rocks, or a deposite.

When a stratum of rocks of a different kind invariably covers another stratum, it is said to be in the order of superposition.

The strata seldom occur in a flat or horizontal position, but generally rise in a certain direction and come to the surface; and in travelling over a country, we pass over their edges which are called the *outcrop*, which shows the different strata. We can thus ascertain the contents without boring.

Formations, are a series of strata that are regarded as being formed nearly at the same time.

Geological Formation, is where strata of different kinds graduate into each other, containing similar species of organic remains.

Coal Formation, is where strata of shale greywacke sandstone and iron stone accompany beds of coal.

The formation of a rock implies the agent by which the rock is formed, or consolidated, and a *rock formation* the effect produced by the agent.

The line of bearing is the lengthwise direction of strata.

The line of Dip is at right angles to the line of bearing.

Inclination, is the angle at which the stratum rises above the horizontal line.

Saddle back, is where the stratum dips both ways, in the form of the letter V inverted.

The anticlinal line, is a line traced on the surface of a country to designate where the strata dip in opposite directions.

The true thickness of a stratum is measured by a line perpendicular to the upper and under surface,

In many instances, strata are bent and contorted in various directions, in this case, it is difficult to find the true dip, or even to ascertain the class to which the rocks belong.

Rocks of the primary class, frequently cover each other in an order, which when viewed on a grand scale, may be said to be *conformable*, but the order of succession is not always easy to trace. Viewed, however, in mountain chains, the general arrangement is 1. Granite, 2. Gneiss, 3. Mica slate, 4. Argillite, 5. transition series, 6. the lower strata with coal, 7· a bed of Limestone, or any other rock in a slate mountain, this is said to be *subordinate*. A bed of conglomerate, or greywacke composed of boulders and fragments of lower rocks is frequently interposed between slate rocks and transition limestone

Unconformable rocks, are Basalt, Serpentine, Porphyry, Hornblende &c.

Unstratified unconformable rocks, occur covering primary, transition, secondary and tertiary strata. Those covering secondary and tertiary strata are evidently the product of subterranean fire, ejected from beneath by some violent explosion. Those also which cover primary and transition strata bear strong evidence of igneous origin.

These changes undoubtedly preceded the existence of the human race, at an epoch very remote. Many inequalities of the earth's surface must be asscribed to these great catastrophes, and inundations which appear to be nearly contemporaneous, and it would be absurd to suppose, that they could have been produced, in every part of the world while man existed. Such a supposition would be contrary to the known and permanent laws of nature.

Longitudinal valleys are those in the direction of mountain ranges.

Transversal valleys are those which cut through ranges of mountains.

Lateral valleys are those which open into a larger valley nearly at right angles to it.

Mountains generally form groups, except those which are volcanic and compose long and lofty ridges, denominated mountain chains.

The principal mountains of Europe and Asia form one immense chain, commencing at Cape Finisterre in Spain, and extending to the eastern extremity of Asia. It is known by different

names in different countries. As, the Pyrenees, Alps, Mount Taurus, Caucasus, Altaic and Himmalah mountains, and the Yobblony in Tartary, extending nearly to Behring's straits, these divide the northern and southern dry land both in Europe and Asia.

One immense chain of mountains runs nearly the whole length of North and South America, a distance of eight thousand miles, called the Andes and Rocky mountains. Mountain ranges present the steepest declivities on that side nearest the sea.

The strata of lofty mountains are generally much inclined, and sometimes nearly vertical. Sometimes beds of limestone occur containing marine shells, which must have been deposited at the bottom of the ocean, and afterwards raised up by some violent convulsion, together with the accompanying strata.

LECTURE IV.

On the Primitive formation.

Those rocks denominated primary are widely spread over the globe in the lowest relative situation, and contain no remains of organic beings.

They are supposed to constitute the foundation on which other rocks lie, and to be the first deposites made after the creation. The same causes which have produced granite and other primary rocks below all others have in some instances reproduced them, covering rocks of the transition and secondary class. Granite is found covering secondary rocks, and sometimes obtruded between them. To account for this, we must suppose granite like volcanic rocks was once in a state of fusion, and was protruded in this state through the upper rocks. Similar facts are observed with regard to other primary rocks, which are believed to be of igneous formation.

The subordinate rocks which occur among primary and also among the transition and secondary are,

Hornblende, Serpentine, Crystalline limestone, and Quartz rock.

GRANITE.

Granite is found at the lowest depths at which man has penetrated, forming vast mountains. Where it rises above the surface other rocks rise towards it, and their angles of elevation increase as they approach it. Proper granite is considered as a crystaline unstratified rock. It is essentially composed of quartz, feldspar and mica, which vary much in their proportions in different specimens. These are denominated by different names. In general, the quartz is grey, sometimes smoky, blue, yellow and green. The feldspar white, reddish, green, or blue, and sometimes tinged with purple. The mica is commonly of a silvery white, but sometimes brown, grey, black and red.

Feldspar constitutes, in general, the largest constituent. Other minerals occasionally combine to constitute granite, as talc, Chlorite &c.

The following varieties are often found associated.

1. *Pseudomorphous granite*, where the quartz and feldspar are associated into a solid mass and the mass penetrated by thin plates of mica, not intersecting each other. The smallest fragments of the quartz and feldspar are often separated by thin plates, the solid angles appear like the projecting angles of crystals.

2. *Porphyritic granite*, this, besides the several constituents, contains imbedded crystals of feldspar, some is fine grained, but in this country it is coarse grained.

3. *Graphic granite*, this variety consists of quartz and feldspar only, the ingredients are usually in lengthwise pieces, so that the cross fracture presents the appearance of Chinese characters. The French geologists have given it the name of *Pegmatite*.

4. *Sienite, or Sienitic granite*, in which Hornblende wholly, or in part, supplies the place of mica. This is for the most part tougher and more durable than common granite.

5. *Talcy, or Chloritic Granite*, is composed of quartz, feldspar and talc, or chlorite. This is a softer species than the preceding. It is called by some protogene.

Granite occurs in masses of vast thickness, which are commonly divided by fissures into blocks which approach to rhomboidal, or pretty regular polyhedral form. Sometimes a columnar structure is given to granite mountains, in other instances, when the quantity of mica is considerable, granite divides into parallel layers, or plates, that have been mistaken for strata. Sometimes it is found in globular masses composed of concentric layers imbedded in other granite, and detached.

The aspect of granite mountains is various, often disintegrating, sometimes heavy and unpicturesque.

Where hard and soft granite are intermixed in the same mountain, the softer granite is disintegrated and falls to pieces, and the harder blocks remain piled in confusion on each other like an immense mass of ruins.

Wherever granite rises high above the surface of the earth, the strata of limestone and other rocks rise towards it.

Granite is found to occur at a lower level in America than in Europe. This is an important geological fact.

Granite sometimes forms veins shooting up into the superincumbent strata; which seems to indicate either that the granite has been in a state of fusion, the heat of which has softened the upper rocks, and forced up the granite in a melted state into those fissures, or else, that the granite and the superincumbent rocks were both in a state of fusion at the same time, and therefore contemporaneous.

The crystallized earthy minerals most commonly found in granite are Schorl, Tourmaline, Prehnite or Pinite, Emerald, Corindon, Axinite and Topaz.

Granite is not rich in metallic veins.

LECTURE V.

Gneiss, Mica-Slate &c.

Where one rock occurs imbedded in another, it is evident that the enclosed rock must be as old as the rock which enclosed it. Hence the rocks enclosed in granite, gneiss and mica slate, must be regarded as primary though unconformable.

Gneiss received its name from the German miners, and is applied to a stratified granite; being composed of the same constituents as granite. Granite frequently passes into gneiss, it often happens, that in the same bed, granite may exist in one part and gneiss in another. Where the quantity of feldspar decreases, and the crystals or grains become smaller, if the mica increases in quantity and is arranged in layers the rock loses its massive structure and becomes slaty, it is then what is termed gneiss; if, on the other hand, the quantity of feldspar increases and the mica diminishes, the structure becomes massive; and granite is the result.

When the mica becomes very abundant and the other constituents are small, it passes into mica slate.

The following are the several kinds of gneiss.

1. *Granitic gneiss*, which is a species of coarse grained granite, and in hand specimens, often exhibits no traces of a schistose structure; but when viewed *in place* on a large scale; some traces of a slaty structure may be observed.

2. *Schistose gneiss*, this is considered to be the most common variety; the structure is foliated, and granular with a laminar tendency; it passes into mica slate by the disappearance of feldspar.

3. *Laminar gneiss*, in this variety different ingredients occupy distinct layers; when the mica, or hornblende is black, the different laminar are distinct and regular. It sometimes exhibits alternating layers of gneiss and mica-slate.

4. *Porphyritic gneiss*, structure more or less slaty with distinct masses of foliated feldspar, of an ovoid form, or distinct crystals. Color white, grey, or reddish.

5. *Amphibolic gneiss*, containing a small proportion of hornblende not sufficient to form hornblende slate. The hornblende is disseminated in black foliated masses from the size of a pin's head to half an inch in diameter, through the rock. Found in the vicinity of hornblende slate.

6. *Epidotic gneiss*, containing hornblende and epidote. The epidote is usually in veins, and generally compact. It is sometimes disseminated through the rocks, giving it a peculiar green tinge.

7. *Augitic gneiss*, in this augite takes the place of the mica, and is of a lively green color. The augite is disseminated in various proportions through the mass, and the slaty structure is quite indistinct.

8. *Anthophyllitic gneiss*, in this variety anthophyllite is disseminated through the gneiss. It is composed almost entirely of quartz, feldspar and anthophyllite, the mica being rare.

9. *Arenaceous gneiss*, composed of quartz and feldspar which are in a finely granular state, embracing sometimes small but distinct crystals of red garnet.

10. *Talcose gneiss*, composed of feldspar, quartz and talc, in structure irregularly schistose.

The declivities of granite mountains, in many parts of the world are covered with gneiss. Mountains of gneiss are not so steep and broken as those of granite, and the summits are generally rounded

MICA-SLATE.

This is frequently incumbent on gneiss, or granite, it passes by gradation into both these rocks.

It is composed essentially of mica and quartz intimately combined. The feldspar occurs only occasionally.

Color silvery, or pearly white, bluish grey, light green, blackish or amethystine, inclining to yellow.

The following are varieties.

1. *Quartz and mica*, the former granular and laminar; the latter in distinct scales and glistening. This is more highly crystalline than the other varieties, and is associated with the older rocks.

2. Containing a larger proportion of feldspar and passing into gneiss.

Talco—Micaceous slate, containing scales of

greenish talc or mica which has lost its elasticity. When the talc predominates it becomes talcous slate.

4. *Amphibolic and Garnitiferous Mica slate*, containing hornblende and garnets.

5. *Staurotidiferous Mica slate.* Mica in fine scales and resembling argillite, except when the strata are viewed edgewise, they exhibit a striped appearance, in consequence of numerous layers of Staurotide, which appears coextensive with the layers of the rock.

6. *Spangled Mica slate*, the basis the same as the last, through it are disseminated numerous thin foliated plates of a deep brown color, somewhat resembling mica, but destitute of elasticity, and brittle, their length, rarely more than a quarter of an inch, usually twice as great as their breadth, exhibiting polarity in their arrangement, that is, their longer axes all lie in the same direction, and the surfaces of the plates in the same or in parallel planes, so as to reflect light from many of them at once, and thus a spangled appearance is produced. These spangles are pretty uniformly diffused.

7. *Argillo—Micaceous slate.* This exists whenever the mica slate passes by gradation into clay slate. Composed of fine scales of mica, closely compacted so as to give it an argillaceous appearance. This rock sometimes contains large beds of white quartz, sometimes fetid.

8. *Arenaceous Mica slate.* In this variety, the quartz is grey, in sandy grains and diffused through the whole mass, not lamellar. The mica is in

fine disseminated scales although the plates are usually parallel to each other. The mass is frequently imperfectly schistose, though more regularly stratified than many other varieties; and sometimes there exists a double set of strata seams; an intermediate variety is remarkably irregular. In general it occupies the highest place in mica slate. It is very nearly allied to quartz rock.

9. *Anthracitous Mica slate.* This is simply a very fine grained mica slate, approximating to clay slate, ii is rendered black and shining by carbon.

10. *Plumbagineous Mica slate*, this exhibits the grey aspect of plumbago.

11. *Conglomerate mica slate*, this contains fragments of mica slate cemented by the hydrate of iron, so as to form a conglomerate.

The mica slate and the quartzose rocks, are with those of gneiss, according to M. Brongniart, so clearly prior to all organic life, that he calls them *hypozoiques*, or inferior to all the rocks which contain organic remains. We hence infer, that all these rocks were formed and arranged before vegetables and animals appeared. The universal absence of all organic remains in these masses, has led every one to this conclusion as a satisfactory certainty.

Most of the minerals and ores found in gneiss also occur in mica slate, Limestone, (crystalline) and Hornblende rock occur in both. Also most of the metallic ores both in veins and beds. Also crystals of garnets are interspersed. Gneiss

and mica slate sometimes graduate into granite, as well as into each other.

Talcose slate and chlorite slate, appear to be different modifications of the same minerals; the prevailing color of both is green. These rocks are soft and of a soapy feel. Easily cut with a knife. The passage from talcose slate to serpentine forms potstone.

Steatite or soap stone is a variety of talc, commonly called talcose rock, the two minerals occur together and mix with each other.

Granular Limestone, when pure, it is composed of calcareous earth, this is the saccharine limestone of the French geologists. It contains no organic remains, and is, therefore, considered as primary. It is yellowish, greenish, or inclining to red. It frequently contains a considerable quantity of siliceous earth, to which it owes its hardness.

That this limestone has once been in a state of fusion, is evidcnt from the crystals of garnets and other minerals found imbedded in it.

Dolomite, called from the French, *Dolomieu*, is a variety of limestone, containing a large proportion of magnesia. It is found in various rocks. It is minutely granular. Color white, often with a tinge of yellow or grey. Occurs massive, often of a slaty texture, lustre glimmering, often translucent on the edges. Softer than primitive limestone, which it often resembles. Dolomite forms vast beds in many rocks. It is strictly a magnesian carbonate of lime.

Serpentine, derived its name from its variegated

colors and spots, supposed, in some specimens, to resemble the spotted serpent's skin. Color green, yellowish green, blackish green, brown, bluish grey, or reddish, colors variously intermixed; opaque, or translucent on the edges; occurs massive, and crystallized. Crystals in the form of four sided prisms, terminated by four sided pyramids. Composition, Magnesia 44, silex 44, allumine 2, oxide of iron 7. 3, oxide of manganess 1. 5, oxide of chrome 2. Infusible. When broken it has a slight degree of lustre, and somewhat of a soapy feel. It is sometimes stratified and sometimes unstratified. It occurs in gneiss and mica and talcose slate as well as in some of the superincumbent rocks. Actynolite, Asbestus, massive garnet &c. are occasionally found in this rock. Its true nature and geological relations are but obscurely determined.

Hornblende rock and Hornblende slate. Color, when it forms the principal parts of rocks, is commonly a greenish black. Massive hornblende in rocks is generally coarsely granular and lamellar. In hornblende slate it is generally radiated and fibrous, and when the fibres are very minute it possesses a velvety lustre.

Hornblende slate occurs in beds in granite, gneiss and mica slate, and occasionally in common slate, it appears to pass by gradation into serpentine, the change is effected by the increase of magnesia.

Hornblende in large lamellar grains intermixed with feldspar forms sienite.

When hornblende and feldspar are more inti-

mately blended they form *Greenstone*, *Diabase*, *Diorite*.

Various intermixtures of Hornblende and Feldspar form rocks commonly called *trap rock*, or *greenstone trap*.

Compact trap, is *basalt*, or *Dolerite* of the French.

Porphyry, derives its name from the Greek and signifies purple, because the rock to which the term was originally applied was of that color. In the modern acceptation of the term, any rock which is compact, or finely granular, and contains distinct imbedded crystals of feldspar, is called porphyry. The base, or paste of most porphyritic rocks is feldspar, and the imbedded crystals are for the most part feldspar.

Geologists have described four formations of porphyry, but their situations are not accurately ascertained.

Whenever porphyry occurs unconformably, covering other rocks, it is evidently more recent than the rock on which it rests, and must be classed with basaltic or trap rocks.

LECTURE VI.

Of the Transition class &c.

Transition, or intermediate rocks cover rocks of the primary class, and are the lowest rocks in which organic remains occur.

They are the principal repositories of metallic ores, metallic veins and beds. Metallic veins very rarely occur in secondary strata.

The following arrangement of transition rocks comprises the lowest rocks in which organic remains occur, and which are metalliferous, or associated with metalliferous rocks.

Conformable strata.

1. Argillite, as also flinty slate and other varieties.
2. Greywacke and greywacke slate, passing into sand stone.
3. Transition Limestone, Mountain Limestone.

Rocks covering transition unconformably.

1. Porphyry, passing into trap and greenstone.
2. Clink stone, passiing into Basalt.
3. Basalt.

Strata covering transition rocks conformably.

Coal Formation.

Argillite, of which roof slate and cyphering slate are varieties; the softer kind found in coal districts is called by some Geologists *Slate-clay*.

Argillite most commonly splits in a transverse direction to that of the beds, unless it be of a kind approaching to shale.

Slate rocks vary much in quality in the same mountain, those which contain a great portion of silex pass into siliceous slate, when they contain a great quantity of magnesia they pass into chlorite or talcy slate, or talco-chloritic slate. Whetstone slate, or hone, is a variety of talcy slate containing fine grains of silex.

Roof slate is generally imbedded in other rocks and does not form mountain masses.

The beds of roof slate sometimes form masses of considerable thickness.

Those varieties of roof slate are preferred which are the least absorbant of moisture, have the smoothest surface and split into thin laminæ.

The mineral contents of slate are Chiostolite, Octahedral iron ore, Iron pyrites, Calcareous spar, Crystallized quartz &c.

Mountains of slate are seldom so precipitous as those of granite, but have often a serrated outline, or rising in *aiguilles*, or needles. They are covered with verdure on their declivities, as they are absorbant of moisture.

Flinty slate differs from common slate in containing a greater proportion of siliceous earth and partakes of the nature of flint. Slate and flinty slate alternate; When flinty slate ceases

to have the slaty structure it becomes hornstone, or petrosilex. If it contains crystals of feldspar, it becomes hornstone porphyry.

It is one of the most metalliferous rocks.

Greywacke and greywacke slate, called by the French *Traumate*, from the Greek *Thrausma*, a fragment. This comprises an interesting group of rocks, partly chemical, and partly mechanical in their structure. The varieties are numerous and very unlike each other. It includes, when taken in a more general sense, every conglomerate sandstone, and fragmentous or arenaceous rock of transition formation, that is anterior to the red sandstone and coal formation. The varieties of rock included in this formation are, conglomerate, Breccias, Quartz rock, talcose aggregate, Classical Greywacke, Greywacke slate, Argillaceous slate, Amphibolic aggregate, Varioloid wacke, Flinty slate, Chert, Jasper, Greywacke Limestone.

Several species of calamites, Equisetæ, and Filices are found in the shistose Greywacke, in Seekonk, Mass. Some of immense size; one fragmentary specimen measured eighteen inches in circumference, having a jointed and striated stem, and appears to be the *Calamites Cannæformis* of De la Beche. It was found in greywacke slate. Other specimens have been found in the same locality, having the ends and part of the stem converted to coal. Similar specimens have been found in Taunton, in the same kind of Grey wacke.

This rock varies in texture from the finest ar-

gillaceous slate and shale through all the grades of sandstone up to the coarsest conglomerate, and breccia. The imbedded nodules are composed of all the variety of primary rocks, cemented by an argillaceous paste, or compact feldspar, or of mica, talc or steatite. Proving almost incontestibly, that the formation has been the effect of igneous action and of some tremendous explosion.

Conglomerate, composed of roundish pebbles, which have all the appearance of having been worn by a continual friction against each other by the force of water, resembling the pebbles found on the sea shore. Varying in size from that of a pea, to a foot or more in diameter. They consist of granite, sienite, compact feldspar, Porphyry, quartz, argillaceous and flinty slate, novaculite, serpentine and nephrite; cemented with the same materials, and exhale an argillaceous odor when breathed on. The cement is semi-crystalline, and adheres very firmly to the nodules.

Breccia, this differs from the conglomerate, by the angular shape of the imbedded fragments, the cement appears to be composed of the imbedded fragments in a comminuted state.

Quartz rock, this is associated with most rock formations but is particularly conspicuous in greywacke, forming veins as well as disseminated. It is of various colors. It occurs massive and crystallized, sometimes exhibiting the regular form, at other times indeterminate. It is one of the oldest of the greywacke formations. Certain local causes appear to have operated to separate the quartz and feldspar from the granite, into masses of considerable size.

Talcose aggregate, this is a slaty rock composed of grains of quartz and sometimes feldspar, with talc or steatite. It is not abundant in the greywacke formation, though many of the oldest varieties have the talcy appearance.

Classical greywacke, this is composed of angular or other shaped masses of quartz, feldspar, Lydian stone, and clay slate, connected together by means of a basis or ground of the nature of clay slate, which is often highly impregnated with silex, thus giving to the rock a considerable degree of hardness. The imbedded portions vary in size, but seldom exceed a few inches in breadth and thickness. Sometimes the mass is colored red by the presence of the red oxide of iron. It often occurs fine grained and passes into greywacke slate.

Greywacke slate, structure slaty, colors either grey or red, composed in a great measure of wacke, and sometimes mica enters into the composition. The layers generally irregular and contorted. It is frequently traversed by veins of quartz.

Argillaceous slate, or argillite, this is associated with greywacke especially in coal districts; the laminæ are sometimes much curved, it frequently passes into novaculite.

Amphibolic aggregate is situated between greywacke slate and conglomerate, its color is greenish or grey, containing a green mineral resembling hornblende, sometimes crystalline.

Varioloid Wacke, usually called amygdaloid; the color is either grey or dark chocolate containing

numerous nodules of the size of a pea of different colors, mostly red or green, consisting mostly of compact feldspar. This formation appears to be the result of heat and steam, occasioned by infiltration through the melted mass.

Flinty slate is associated with greywacke in many places. It appears to be produced by the proximity of granite, porphyry, or talc. It is an altered variety of the greywacke. This rock exhibits scarcely any marks of stratificatioa; but in some masses, the former slaty structure is distinctly visible. In fine, it appears to be the greywacke slate fused and indurated.

Chert, associated with greywacke, appears to be an argillaceous limestone converted by fusion. It is often found with limestone. It is grey passing into blackish brown; fracture conchoidal, or splintery; lustre glistening between resinous and vitreous semitransparent or translucent.

Jasper, this is associated often with greywacke, and is evidently the result of an high degree of temperature. It differs little from a siliceous flinty slate, is generally colored red, brown, or yellow, opaque. In some situations beds of Jasper alternate with slate. Lydian stone is sometimes called black Jasper. Its color is generally owing to the peroxide of iron which is converted from the protoxide by heat. It also contains clay and silex, originally slate impregnated with the protoxide of iron; the iron afforded a flux for the fusion of slate, and thus Jasper would be produced.

Transition limestone, *Greywacke limestone*, tex-

ture subcrystalline, translucent on the edges; most of the colored marbles are transition limestone. Colors, bluish, grey, red, brown, black, sometimes veined, striped and spotted. It occurs in beds, alternating with slate, greywacke, greywacke slate and coarse gritstone.

The strata are usually bent and contorted. It contains a great variety of marine shells and must therefore have been formed under the ocean, and as it contains trap and amygdaloid, it must have been subjected to violent igneous action.

Some of this limestone is metalliferous, containing iron, lead, zinc and copper.

Many of the organic remains in the transition rocks are of genera, which do not occur in the secondary rocks, as encrinites, madrepores and coralites. Vegetable remains, except in slate rocks, are rare. The trilobite is peculiar to transition rocks. Orthoceratites, gryphites and nummulites are found in this formation.

Conformable transition rocks cover the primary and sometimes alternate with them, they are also associated with the lower beds of the coal formation.

All rocks under the great coal formation belong to the primary, or transition, and all above, when conformable, belong to the secondary or tertiary formations.

Where the coal is absent, it is not easy to define the different formations.

LECTURE VII.

Coal Formation.

Previously to arriving at the present formation, we have discovered but few remains of terrestrial vegetables, or animals, hence we infer that there were but few islands or tracts of dry land emerged from the water. But we are now to contemplate a most important and extensive change in the condition of the globe, at least, in that part in which coal is found.

For a depth of two thousand feet or more, almost exclusively, the remains of terrestrial plants are found; such as have grown on dry land, or in marshes. Carbon, in the form of coal, constitutes extensive beds in the series, varying in thickness from a few inches to thirty feet, or more, alternating with beds of shale, argillite, greywacke, greywacke slate, iron stone, indulated clay, quartz rock, sandstone &c. In this, the remains of vegetables are distributed throughout the whole series, which, taken together are called *coal measures.*

The coal strata appear to have been deposited in the vicinity of tracts of dry land, containing

rivers, marshes, fresh water lakes and mountains.

The marine beds which are the foundation of the coal strata, and also surround them, must have been raised from the bottom of the ancient deep, before the vast accumulation of vegetable matter could have been formed.

This change appears to have been attended with another remarkable effect, after this period metallic veins have been rarely formed.

The vegetable remains belong to species found in tropical climates principally, at the present time, and yet, they appear to have grown near the spot where they are entombed. This can be accounted for only by supposing that the earth, generally, was of a pretty high temperature at the time of their flourishing.

A district with its peculiar series of strata is called a *coal field.*

Each district has its peculiar strata unconnected with any other. Sometimes the coal rests on granite; at other times on limestone, and sometimes on greywacke, or greywacke limestone. The coal in Rhode Island alternates with quartz rock of a fibrous structure.

The strata containing coal are nearly horizontal.

In some coal beds in Europe, there is a transition from marine calcareous strata with animal remains, to fresh water strata with terrestrial vegetables; which implies, that the subjacent limestone had been gradually but unequally raised above the sea, and during its elevation, some parts remained immersed in the ocean, while oth-

er parts were covered with vegetable depositions.

Coal strata are often arranged in basin shaped concavities, which appear to have been lakes that were gradually filled by carbonaceous depositions.

Strata under a bed of coal are frequently similar to those over it; and the same series are repeated in some mines several times.

A fault is a break or intersection of strata by which they are commonly raised up, or thrown down.

A Dyke is a wall of mineral matter, cutting through the strata in a position nearly vertical.

The thickness of dykes varies from a few inches to twenty or thirty feet, or more. They are composed of indurated clay or basalt.

Contorted Strata are those which are twisted or bent.

Coal strata frequently present remarkable contortions, which are probably owing to a lateral force that has compressed them into a zig-zag form.

Coal strata near the surface, are generally in a soft decomposed state, and intermixed with earthy matter; in this case, the soil is generally of a darker color.

In general, coal improves in quality as it sinks into the earth. It is more highly carbonized and compact.

Vertical Joints in coal are called *slines*; the oblique shorter joints, *cutters*.

Coal is divided into two species, but of these there are various kinds, viz. Brown coal and Black coal. Brown coal, called also *lignite*, is

principally found in alluvial or diluvial ground, it contains besides charcoal and sometimes bitumen, various vegetable principles, and the branches or trunks of trees partially decomposed, which mark its origin. Such is the lignite of Martha's Vineyard.

Common coal is composed of charcoal, bitumen and earthy matter; the latter forming the ashes, when it is burnt; the ashes vary in different kinds, from 2 to 20 per cent. The proportion of bitumen from 20 to 40 per cent.

Anthracite, is a mineral approaching to the nature of Plumbago; it consists nearly of pure carbon, hard and difficult to ignite; and often exhibits a very high degree of lustre, sometimes a metallic one, often irridescent.

It is commonly found in transition rocks, but sometimes in regular coal strata.

The anthracite of Pennsylvania is not regarded by European Geologists, as the *true* anthracite, but only a variety of common coal containing but little bitumen.

The Rhode Island coal approaches nearest the European Anthracite.

Anthracite in general, is so completely mineralized as to present no traces of vegetable origin; but in some bituminous coal, as in the Pictou and some European coals, there may be found regular strata of vegetables, converted into true mineral coal, preserving when separated perfect impressions of leaves and other parts of vegetables. Hence it may be fairly inferred that all coal is of vegetable origin.

In order to account for such a mass of vegetables as must be requisite to form coal beds; it may be supposed that vegetation, in the primitive ages, was much more rapid under an high degree of temperature, and in an atmosphere probably much more highly charged with carbonic acid, than it was after the creation of man. Vegetation would tend to absord the carbonic acid, or rather the carbon, setting free the oxygen and purifying the air for the respiration of animals.

The most common vegetables found in coal fields are referred to the Cryptogamous class in Botany, Equisetums (horse tails) of gigantic size, with jointed and striated stems, hence called calamites, and Lycopodiæ allied to ferns. From the fact that the plants are found erect in many coal formations, we may infer that they grew near the place where their remains are entombed.

Wood coal, or Lignite, is found in diluvium, or alluvium, and appears to have been formed of heaps of trees &c., buried by inundations under beds of clay, sand, or gravel. The woody parts have probably undergone a degree of vegetable fermentation under the pressure of the incumbent earthy matter, by which they have been carbonized and consolidated.

In common coal, the vegetable extract and resin have been destroyed and the carbon and bitumen remain.

Coal may have been formed from peat, if we admit that northern latitudes had the temperature of tropical climates during the geological epoch, when the vegetables flourished that are found in

the coal strata; the peat of that period would partake of a different character from recent peat beds, and might be produced by the rapid decomposition of large terrestrial and marsh plants, which have not woody stems and therefore much sooner decomposed.

Thick beds of peat might have been formed in the primitive ages in a very short time; vegetation then flourishing and decaying under an high degree of temperature and a moist atmosphere, charged, as we may suppose, with carbonic acid.

The fossil vegetable remains, found in different parts of the world in coal fields, under different latitudes belong, in general, to the same genera, and their species are nearly identical. Those in America, Greenland, Nova Zembla, India, and New Holland, belong to the same families as those in Europe. To account for this, we must admit that the temperature of the globe was pretty uniformly the same under the different latitudes, and the temperature that of tropical climates, at the epoch of the coal formation.

The regular, or great coal formation, seldom occurs at a great elevation above the level of the sea; it is found near the foot of great mountain chains, or in valleys, or in islands of the sea.

Much of the coal of the Northern and Middle States, is that kind called anthracite containing little bitumen, and emitting but little flame and smoke in burning.

The quantity of coal raised in England is immense, and it is to this substance and the iron ore found in the same deposit, that the nation

owes a great part of her commercial prosperity; for to the abundance and cheapness of both these articles in various districts, they are indebted for a large proportion of their manufactures; the same series of beds not only furnishing fuel for working the steam engines, but also iron for their construction.

Here we see, evidently, design and intelligence in the Great Author of Nature. The accumulation of vegetable matter at a remote epoch in the history of the world, for the consumption of creatures that afterwards exist on its surface, must strike every inquiring mind with an idea of Omniscience and beneficence; but when the upturned, twisted and contorted strata, so common in coal districts, are taken into consideration, design is not so apparent; and this might, therefore, be regarded as a bar to the ingenuity of man, in extracting the useful combustible.

When, however, we examine more closely the subject, we find that the shattered and contorted condition of the rocks, though it may embarrass mining operations for a time, is highly advantageous. The *faults* so cross each other that the surface, if it could be examined without its covering of vegetation and *detritus*, would present much the appearance, on a great scale, as a frozen surface of a great lake broken to pieces and reunited by subsequent frosts. Masses of fractured strata are thus often bounded by *faults* which prevent the passage of subterranean waters from one mass into another, and the miners in collieries situated in one particular mass, have

only to contend with the waters in it; whereas, if the strata were always horizontal, unbroken and continuous, the abundance of water that would flow into the workings would render them so difficult and expensive, that the extraction of the coal would be abandoned.

The vegetable remains belonging to the coal formation, generally, appear to be chiefly derived from various grasses and reeds, and plants of the cryptogamous and succulent tribes, many of which are not known to grow, at present, on the surface of the earth. From the latter of these the coal itself appears to have proceeded. In the mountain limestone above the coal, and in the different members of this formation, existing between this and the lias, vegetable remains appear to be of rare occurrence; so that particulars of such as have been discovered in these situations may furnish much useful information, and especially with respect to those fossils which have been supposed to have derived their origin from wood.

It has been asserted that wood, or parts of trees have been found in coal and in the accompanying coal measures; this requires further confirmation; except in the lignite, description has not, hitherto, been so exact as to preclude doubt on the subject. It is pretty certain, from recent and more minute observations, that no plants of ligneous stems are found in the great coal measures. Those traces, which have given rise to the idea of trees, are, it is highly probable, gigantic succulent plants of the Equisetæ and Cactus tribes; and may thus have led to the belief of trees, from the ligneous

hardness which large plants of this kind may have acquired, and which, perhaps, may be traced in their mineralized remain.

The size which these fossil plants have attained compared with the cactuses in the United States and Europe, may lead to a doubt as to the opinion of their agreement with recent cactuses. But to be enabled to form a correct judgment on this point, it is necessary to know the state in which these plants exist where the soil and climate are such as to allow them to develope themselves in their native luxuriance. Humbolt's researches in the equinoctial region of South America, supply us with the most appropriate and satisfactory information. He says: "The hill of calcareous breccia, which we have regarded as an island in the ancient gulph, is covered with a thick forest of columnar cactus and opuntia, some thirty or forty feet high, covered with lichens, and divided into several branches in the form of candelabras, wearing a singular appearance. Near Maniquarez, at Punta Araya, we measured a cactus, the trunk of which was four feet nine inches in circumference. The European, acquainted only with the opuntia, in our hot houses, is surprised to see the wood of the plant become so hard by age, and it resists for centuries, both air and water, so that the Indians of Cumana employ it in preference for *hords* and *doorposts*. Cumana, Caro, the island of Margaretta, and Curaccao are the places in South America that abound most in the plants of the nopals. There only, a botanist can compose a monography of the gen-

us cactus, the species of which vary, not only in their flowers, and fruits, but in the form of their articulated stems, the number of *costæ* and the disposition of the thorns; the division of property are marked by hedges formed of the agave and cactus. At San Fernando, South America, the soil abounds in aquatic plants with sagitate leaves, some of these aquatic plants are from eight to ten feet high. In Europe, their assemblage would be considered a little wood." He also mentions a kind of bamboo, which the Indians call *Jagua*, which is found near San Fernando, more than forty feet in height. "These, he observes, cannot but remind the admirer of fossils of the vast fossil bamboos which are found in the sandstone, accompanying coal." Speaking of a rock of considerable height and magnitude, he observes: "Euphorbium, Cacalia, Klinia and Cactus, which are become wild in the Canary Islands, as well as in the South of Europe and the whole continent of Africa, are the only plants we see on this arid rock: being plants which draw their nourishment rather from the air, than from the soil in which they grow." He also remarks, "It is not, in general, by mosses and lichens that vegetation in the countries near the tropics begins. In the Canary Islands, as well as in Guinea, and in the rocky coasts of Peru, the first vegetables that prepare the mould for others, are the succulent plants."

These interesting observations of Baron Humbolt, taken into consideration with the appearances exhibited by the fossils accompanying coal,

tend to the further evidence of the formation of that substance. From its chemical characters, its bearing the impressions of vegetables, and being surrounded with vegetable remains in the roofs and floors of the mines and the accompanying coal measures, its vegetable origin may be fairly infered. The examination of the various fossil vegetables which accompany it has determined that they chiefly belong to the grasses, reeds, the cryptogamous and succulent plants; and point out the kind of vegetables which most abounded, and, perhaps to the exclusion of trees and arborescent plants, at that period, when the land first rose from the dominion of the waters. It is true, that an exact agreement between the forms and markings of these fossil remains and of those of the succulent plants which are offered to our observation in the present day, is not often the same; but it should be considered that analogy will not authorise the expectation of an exact agreement, since it is rarely to be found between the fossil remains, and the vegetables now existing, owing to the extinction of whole tribes from which those fossil remains have proceeded, Besides, considerable differences must result from the greater size observable in the fossil vegetables, especially in those of the succulent tribes, than in those of modern creation. Nor should the difference be unregarded which depends on situation and climate; the succulent plants of Italy differ materially in size from those of South America and of other regions in the warmer climates.

From the discoveries and observations made, we may safely infer, that, at some very remote period in the existence of our planet, it must have abounded with plants of the succulent kinds, and, as it appears from their remains, in a great variety of forms and luxuriance of size. These, from what is discoverable of their structure, armed with *Setæ* and spines, were not formed for the food of animals; nor from the nature of the substances of which they were composed, were they fitted to be applied to the various purposes for which wood, the product of the earth at a subsequent period, has been found to be so excellently adapted by man. Their remains, it must also be remarked, are now found in conjunction with that substance which nature has, in all probability, formed from them, and which by the peculiar economical modification of its combustibility, is rendered an invaluable article of fuel. If this be admitted to be the origin of coal, a satisfactory cause will appear for the vast abundance of vegetable matter with which the earth must have been stored in its early ages; this vast and in any other view, useless creation, will thus be ascertained to have proceeded from a beneficent arrangement by Providence for man, the being of a creation of a later period.

According to M. Al. Brongniart, no kind of marine plants occur in the coal measures; they are all of land origin. He enumerates the following:

Equisetum, or horsetails; Calamites, or reeds; 12 species. Ferns; 21 kinds of Sphœnopteris;

2 of Cyclopteris; 11 of Nevropteris; a Glossopteris; 46 speeies of Ptecopteris; a Lonchopteris; 4 kinds of Odontopteris; 41 of Sigillaria. 7 species of marsilleaceæ or the pepperwort tribe. 10 species of the Lycopodiaceæ, or the club moss. 2 of Selagmites. 34 of Lepidodendron; 5 of Lepidophyllum; 4 of Lepidostrobus; 5 of Cardiocarpon; 8 of Stigmaria; 3 Palms; a Canna; 14 species of four monocotyledons,

On the above enumeration, M. Adolphe Brongniart remarks: "from which it results, that we have not found in the coal formation any plants of the classes of the agames, the cellular cryptogames, phanerogames gymnospermes, nor phanerogames dicotyledons; while of about 200 known species, there are more than 180 belonging to the vascular cryptogames, and 20 to the phanerogames monocotyledons."

"We only find these terrestrial or lacustrine vegetables. No shell, no fish, of an origin purely marine, is cited in the coal or in the coal rocks properly so called."

Marine plants are not found in the coal measures but in the limestone above them; hence it is evident that the Magnesian limestone was formed at the bottom of the sea, and deposited after the great coal formation.

In the opinion of M. Adolphe Brongniart, the antiquity of the formations in which the vegetables of the first period of creation, are found, prove, what we might admit *a priori*, that life began on the earth by the vegetable kingdom, That vegetation preceded all animal life, precisely as Moses has stated.

LECTURE VIII.

Secondary Formations.

Secondary rock formations comprise all the regular strata that cover the transition rocks, and coal measures, and in Europe terminate with chalk. They are composed of vast depositions of sandstone and conglomerate beds, separated by beds of clay and sand.

The secondary limestones are less crystalline and more soft and earthy than transition and mountain limestone, but some yield a beautiful marble used in the arts. It abounds in a great variety of organic remains, consisting of corals and many species of Zoophytes, and other radiated animals; some species of crustacea, a few remains of fish and a great variety of marine shells. It forms a considerable stratum in various parts of the world, and abounds, in many places, in valuable ores of lead. In some parts it is estimated to be *nine hundred feet in thickness.*

The secondary strata abound almost throughout, especially in the *lower secondary*, with remains of marine animals.

The remains of fresh water animals, in some of the secondary strata, and parts of terrestrial vegetables also occur; proving the existence of tracts of dry land at the time the strata were deposited.

The secondary strata, in some one, or other of their varieties, cover a large portion of the habitable globe.

Some beds of imperfect coal and lignite occur in the secondary strata.

Few metallic veins, or beds, except iron and lead, occur in the secondary formation; neither are there any rare species of crystallized minerals.

In this formation occur *rock salt* and *gypsum*, in a rock consisting of red, or bluish grey sand, or clay marle, or both. Hence called *Saliferous rock.*

The lower secondary or third series, include those rock strata which in addition to the relics of the transition class, contain univalve marine shells, *not chambered*, with stiped and mostly *culmiferous monocotyledonous vegetables*,

Upper secondary, or fourth series, includes those strata which, in addition to the relics of the third series contain *oviparous vertebrated animals.*

After the deposition of the coal strata, another important change appears to have taken place in the condition of our planet. The upper secondary strata contain prineipally the remains of marine animals; here the bones and entire skeletons of enormous reptiles are first discovered; but no remains of mammiferous land quadrupeds, except in one or two instances, have been found.

New red sandstone, so called to distinguish it

from another sandstone found in the transition rock.

This is a very extensive and complex formation.

Its prevailing mineral character is siliceous. It is of different colors, most commonly verging to a red, which is evidently a protoxide of iron converted into the *peroxide* by heat.

It may be divided into three series, or the upper the middle and lower beds. These are subdivided into varieties and all included in the great red sandstone formation, viz. Conglomerates, red and grey. Trap conglomerates, Sandstone red and grey. Micaceous schist. Variegated sandstone. Shale, Bituminous shale, Bituminous marlite, Bituminous limestone, Fetid limestone, Argillaceous carbonate of lime, or Lias.

Fragments of the older rocks occur in the different beds of sandstone, and sometimes the beds are formed almost entirely of these fragments. It appears that the disintegrating causes which broke down part of the ancient rocks, acted at successive intervals of short duration; succeeded by long periods of repose in which the calcareous deposites were made.

In magnesian limestone, in this divisirn, occur the fossil encrinites, ammonites, terrebratulites and muscles.

The sandstone appears principally to be formed by the disintegration of the unconformable rocks in the lower formations. *This group is estimated at not less than* 2100 *feet in thickness.*

Tracks, or impressions of the feet of an animal resembling a turkey have been found in the sand-

stone near Montague, in Massachusetts; but to what animal it did properly belong is not accurately determined, They are also found in the same rock in other parts of the Connecticut valley.*

Vegetable remains are also found in this formation. Such as the Calamites, Lyeopodite, the Voltzia and many of the Genus Ficoides. Ichthyolites are found in Bituminous marlite, also the family of Molusceæ, Zoophytes and Radiatæ.

The remains of fishes occasionally occur in all the secondary strata. Fossil fish have been less accurately ascertained, as to the genera to which they belong, than the other kinds of animal remains, because the science of fishes is not so far advanced as other branches of Zoology.

Ichthyolites, or impression of fish, are found in abundance in the New Red Sandstone group in Sunderland, Mass, and in Middletown, Conn. These occur in Bituminous Shale and Bituminous Marlite; a thin layer of Carbonaceous matter marks out the spot where the fish lay; except the

*The following interesting notice is from a Northampton paper.

Bird Tracks in Stone.—Prof. Hitchcock of Amherst, passing over our side walks, discovered distinct prints of the feet of a very large bird; three tracks succeeding each other, in two places on the paving stones. One set of tracks is on the pavement in front of the Court House steps, and the other on a large flat stone in front of the east door of the old Meeting House. These stones were brought from the banks of the river at South Hadley Falls and are of the sandstone formation.

The tracks are about one foot and nine inches apart, and must have been imprinted when the stones were in a soft state, by some larger bird than is now known to inhabit these regions, excepting the wild Turkey. The Professor mentioned having seen ten of these tracks in succession in a stone at Gill, we believe, and the Franklin Mercury, not long since, gave an account of similar impressions.

head, whose outlines are rendered visible only by irregular ridges and furrows. Sometimes the impression is perfect, but most commonly the outlines are much deranged, so that it becomes a difficult task to ascertain the species.

In the magnesian limestone are found the fossil *Productus* and *Spirifer*,

Some of the magnesian limestone is fetid when rubbed.

Magnesian limestone affords the most durable building stone that is found in the upper secondary series.

Gypsum and Rock salt occur in the new red sandstone. But they are not confined to this formation. Salt springs rise in the coal strata, and gypsum and rock salt, are found in the upper Secondary and Tertiary beds; but the repositories of these minerals are more characteristic of the new red sandstone.

Gypsum, both fibrous and massive, occurs in the new red marl, and sandstone; the fibrous alternates in seams the massive is granular and occurs in regular beds and blocks, in the red marl.

Gypsum is associated with rock salt.

Anhydrous Gypsum is entirely free from water, and is much harder and heavier than common gypsum. Rock salt is sometimes situated near the feet of high mountains and appears to have been deposited originally in salt water lakes. It is sometimes surrounded by red sand stone. Hungary and Poland afford the most extensive repositories of rock salt in Europe.

In Caramania in Asia, rock salt is said to be

so abundant and the atmosphere so dry, that houses have been built of it.

In Peru, rock salt is said to occur at an elevation of 9000 feet above the level of the sea. Salt springs and *licks* abound in some parts of the United States. Near some of these places at a little depth below the surface the bones of the great Mastodon are frequently found.

Rock salt has not been found in the United States.

The new red sandstone appears to be produced principally by the agency of water, which first wore away the rocks, and then transported their fragments and deposited them where we now find them. They were probably consolidated by the agencies of water, air and heat. It was deposited beneath the ocean and afterwards elevated. The fossil vegetables found in it were evidently marine, or grew in salt water; and the animals are, as far as our knowledge extends, of marine origin. The temperature at the time of their formation was evidently, much higher than at present; as the fossil remains found in the sandstone, are allied to those genera now peculiar to the torrid zone.

The fact appears pretty well established, that these have been several successive creations and extinctions of animals and plants on our globe, previously to the production of the present organized beings.

According to Brongniart, there have been four periods of vegetation since the creation, each differing from the other by a marked distinction in

the species and even genera of plants, and in the numerical proportion of the different kinds.

During the first period, the strata, from the lowest fossiliferous rocks to the lower part of the new red sand stone, were deposited. The second period includes the time in which the new red sandstone series were forming. The third period, the vegetables lived which are found between the new red sandstone and the chalk, including the latter. The fourth period commenced after the deposition of the chalk, and reaches to the highest of the tertiary deposites.

During each successive period, the vegetation became more perfect. Cryptogamous plants predominated during the first period, while dicotyledonous and monocotyledonous during the last period. The same is true in regard to animals. Those found in the lower rocks are extremely simple in their organization, and vertebral animals, except a few fishes, do not appear lower down than the new red sand stone, while land animals begin to appear higher in the series.

LECTURE IX.

Of the Lias Formation.

The term *Lias* is supposed to be a corruption of the word *Layers* it being in thin strata or layers; and is argillaceous limestone of a dark grey color; and associated with beds of clay. It is best characterised of all the secondary formation, both from its mineral character and the fossil remains found in it.

The marly stratum may be regarded as the first approach to a formation resembling lias in its characters. This occupies the upper part of the bed, and the lias limestone the lower. The latter has frequently a yellowish white color, or smoke grey.

If iron enter largely into the composition, it forms when burnt, an excellent water cement.

The finer kinds of lias are used for Lithography; the best is found on the Rhine. It is, when polished, a beautiful stone, moderately hard and compact, and is highly absorbable of water and oil.

The beds of lias, clay and limestene are particularly distinguished by the number and variety of

organic remains which they contain. Such as ammonites, nautulites, belemnites, and other species of chambered shells.

Univalved unchambered shells are not numerous.

A great variety of bivalve shells occur.

The *gryphea incurva*, and Pentacrinites abound in the lias.

The most remarkable organic remains, are certain species of fish, and vertebrated animals allied to the lizard tribe.

The Ichthyosaurus, or fish lizard, had a head resembling a dolphin, and numerous conical teeth. The eyes were of enormous magnitude, measuring ten inches in diameter, and they have been found from five to twenty feet in length. They naturally breathed air, for which purpose they were oblidged to swim on the surface of the water. Several species have been discovered.

The Plesiosaurus resembled the former in many particulars, in its osteology; its vertebræ approach those of the crocodile. Its neck was longer than its body. The dimensions were as follows:

Cervical vertebræ,	35
With the dorsal ribs,	6
Back and loins,	21
Tail,	26
Sacral,	2
Total,	90

It is considered as a marine animal intermediate in its structure between the crocodile and Ichthyosaurus.

The *Sea-serpent*, which has frequently visited the waters of New England, is supposed to belong to the genus *Plesiosaurus*, Its existence has been so often attested by thousands of competent witnesses, that its identity is no longer problematical.

The organic remains in lias are not always marine. It contains the bones of the turtle and crocodile; and also terrestrial plants. Proving that dry land must have existed in the vicinity previously to the deposition.

Oolite, is so named from its being composed of small grains of the size of mustard seed, or the roe of fish; of a yellowish color alternating with beds of clay, marl, sand and sandstone. This formation in England has an aggregate depth of 1200 feet. When the globules attain the size of a pea, the aggregate is called *Pea stone*, or *pisiform Oolite*. Some beds of Oolite are used in Architecture but it is liable to disintegration.

Fossil genera of animals are found in the Oolite which differ remarkably from those found in the lower strata, and indicate a considerable change in the condition of the globe, or in those parts of it where the strata are deposited.

Most of the genera of fossils found in the lower strata belong to the *acephalous moluscæ* or such as had neither heads, nor eyes, and inhabited bivalve shells.

In the Oolite the genera and species ofunivalve unchambered shells are more numerous, and the individual shells of several species abound in some of the strata.

Now, as these animals had heads and eyes and

moved on their bellies like the land snails, we may infer that they did not live in deep seas, where the sense of vision could not be available, they lived and moved in comparatively shallow water near the shore.

The vertebrated animals whose remains are found in Oolite, are fishes and reptiles of the same genera as those discovered in the Lias; the reptiles undoubtedly belong to the crocodile genus, and had feet like the living species of crocodile, hence it appears there were dry land and rivers in the vicinity.

Madrepores, and Millepores, together with fossil sponges and alcyonia, also occur in this formation.

More than twenty species of top shaped spiral shells and several species of echinites are found in the Oolite.

The Oolite is not known to exist in this country, except in one or two instances, but in England, it is a very extensive formation, and affords abundant materials for building. The Island of Portland near the Isle of Wight abounds in this stone, hence called *Portland stone*. Westminster Abbey, St Paul's Cathedral, Somerset House and St James Palace are constructed of this stone. In the Portland quarry are found petrified trees nearly resembling the Palm, which is a tropical production. This affords, among many others, a proof that England must have once been under water, and the appearance is such as to induce the belief that the surface undulated, or must have gone up and down several times.

Many parts of the surface of the globe afford proof of the rising and falling of land; the most remarkable of which are Pozzuoli formerly called Putioli. These are remains of the temple of Jupiter Serapis, and are known to have once been under water from the perforations made in them by shell fish. These pillars must have fallen and risen again. In 1822, there were tremendous earthquakes in Lima, in consequence of which, the land to the extent of one hundred miles along the coast of Chili, rose from five to seven feet. On the coast of Sweden, an ancient Sea level has been discovered between two and three hundred feet above the surface of the water; Greenland is known to be sinking; yet such movements are very gradual, except occasioned by earthquakes.

The Oolite is included in three divisions viz. the *upper* the *middle* and the *lower*.

The lower division of the Oolite, comprises, 1. An imperfect, dark brown limestone,intermixed with sand and the oxide of iron. 2. Beds of clay and fuller's earth. 3. The great Oolite, of considerable thickness, composed of minute globules and broken shells, united by yellowish earthy calcareous cement. 4. Forest marble, and a sandy calcareous stone dividing into shale and carbonaceous matter.

The univalve shells are the most numerous in the thin beds, and the bivalve in the thicker beds. 5. A brown stone called *cornbrash*, in detached masses, cemented by clay, abounding in shells and other fossils.

The Middle division of Oolite, consists 1. of

siliceous and calcareous sand stone. 2. Coralline limestone, containing numerous madrepores, in some parts called *coral ragg*. 3. Oolite resembling the thin species in the lower division.

The beds of the middle Oolite pass into each other, and may be regarded as one formation. Bones of the lizard shaped animals have been found in this division.

The upper division of Oolite comprises 1. *Portland Stone*, which is a calcareo siliceous free stone, with beds and nodules of flint. It is not extensive. It is succeeded by beds of limestone.

In some of the Oolite are beds of slate containing the impressions of the outer cases, or elytra of winged insects, and bones of a small animal of the opossum genus; and also of the megalosaurus, or gigantic lizard. Calculating from the size of the bones the animal was 40 feet long and 12 feet high. Also the legs and thigh bones of birds, teeth, palates and vertebræ of fishes, with crabs, and lobsters.

The occurrence of wood and beds of lignite in the Oolite, leads to the inference that dry land existed in the vicinity, at the period when the Oolite beds were formed.

Chalk. In England, the geological position of chalk is over the Oolite formation, though the arrangement varies in different places. Chalk if found at all, is in a very limited quantity in the United States.

The position is as follows: Upper, or Portland Oolite, Limestone, conglomerates, Sandstone and Clay, called *Wealden beds*, Lower green sand, Blue clay, called *galt*, upper green sand, chalk.

Chalk is found of different colors, it is generally white or yellowish white; occurs massive; fracture earthy; meagre to the touch; dull; opaque; soft; soils the fingers; adheres to the tongue; gives a white streak. Effervesces with acids, burns to quicklime.

Composition. Clay, silex and carbonate of lime. The greatest proportion is carbonate of lime.

It is the highest stratum of the secondary formation.

When compact, it is used as a building stone.

The upper part of the chalk throughout England is characterized by the presence of numerous *flint stones*, more or less arranged in parallel lines; seams of this substance not only occur in a line with the flints, but also traverse the beds diagonally.

When chalk is freed from silex, it contains, according to M. Berthier, in 100 parts, 98 lime, 1 magnesia and a little iron, 1 alumine.

In the lower parts of the English chalk deposites, the flints disappear becoming gradually more rare in the passage from the upper to the lower parts.

From this circumstance, the chalk has been divided into two divisions, viz. The upper, or *chalk with flints*, and lower, or *chalk without flints*.

This division, however, does not always hold, for in some parts of France, the lower chalk contains an abundance of flint and chert nodules, where it passes into the upper green sand. There can be but little dependence placed on minute divisions of rocks, even within the distance of a few miles.

In some parts of England, the chalk beds are characterized by the presence of small and irregularly rounded grains of quartz, probably of mechanical origin, occasionally disseminated through the mass in great abundance. These beds are also remarkable for a great variety of organic remains. They become suddenly replaced by others, where the quartz entirely disappears.

Green sand which appears to graduate into the chalk, or cretaceous group which is charged with green particles, is composed of Silex, 0. 50, protoxide of iron 0. 21, alumine 0. 07, potash 0. 10.

The greenish or reddish nodules disseminated through the same rock at Havre, contained :— phorphate of lime 0. 57, carbonate of lime 0. 07, carbonate of magnesia 0. 02, Silicate of iron and alumine 0. 25, water and bituminous matter 0. 07, Here we readily perceive a different composition of the nodules and grains. Respecting the former M. Al. Brongniart observes, that the phosphate of lime sometimes so abounds as nearly to constitute the whole substance.

The galt, is an argillaceous deposite of a bluish grey color, frequently composed of clay in the upper, and marls in the lower part, containing disseminated species of mica; it effervesces strongly with acids.

The lower green sand is formed of sand and sandstones of various degrees of induration, principally of iron grey and green colors. The former constituting the upper part and the latter the lower portions; which are frequently argillo—arenaceous, particularly at bottom.

The whole of the chalk series, taken as a mass, may, in England and a considerable portion of France and Germany, be considered as *cretaceous* in its upper part, and *arenaceous* and *argillaceous* in its lower part.

The greatest thickness of the chalk strata in England may be estimated at from *six to eight hundred feet.*

Humbolt observes, after noticing the great intermixture of the sandy calcareous and argillaceous beds, in the formation below chalk, *that nature seems to have relented in her tendency to form complex mixtures when chalk was deposited.*

Chalk which contains a considerable portion of magnesia, may generally be known by an appearance of dendritical spotted delineations on the surface of the natural partings, and by minute black spots, like grains of gunpowder, in the substance of the chalk.

The organic remains in the chalk formation are exclusively marine. These are echinites, particularly the helmet shaped species, called *ananchytes*, and the heart shaped species called *spatangus*, cor anguinum. The chambered shells called Scaphites, Hamites, Turrilites and Baculites are regarded as peculiar to the chalk formation; it also contains Ammonites, Belemnites and Nautilites.

Numerous organic remains of Zoophytes in the state of flint, particularly of Sponges and Alcyonia, and various species of bivalve shells, occur in chalk, but comparatively few spiral univalve shells.

It is probable that the deep ocean in which

chalk was deposited was not suited to the inhabitants of such shells, for the animals had heads and eyes and required shallow water to see their food. Teeth, palates and scales of fishes occur in chalk.

The vegetable remains in chalk, are few, and those appear to belong to the family of *Fuci.*

There appears to have been a considerable interval between the epoch when the chalk was deposited, and the period when it was covered with the tertiary strata; during which the surface of the extensive mass of chalk was deeply furrowed and excavated, before a new series of strata were deposited upon it, destined to support a new creation of animals of a superior class, entirely different from those which have left their remains in the subjacent strata. In some situations however, the tertiary strata appear to rest *conformably* on chalk, and present no indications of any interruption in the succession of regular deposits.

The Ferruginous sand Formation, is considered as equivalent to the cretaceous group, by Dr. Morton, who describes it as occupying a great part of the triangular peninsula of New Jersey, formed by the Atlantic; Delaware and Raritan rivers, and extending across the state of Delaware, from near Delaware city, to the Chesapeake; appearing again near Annapolis in Maryland; at Lynch's Creek, in South Carolina, at Cockspur Island, in Georgia; and several places in Alabama, Florida &c.

When Chalk was formed, the land must have been again submerged as it had been in some

previous formations. As this is exclusively a *marine* formation. One mile below the surface of this formation *foot-marks* have been discovered, supposed to be those of the tortoise, which is an amphibeous animal. No viviparous vertebrated animals are found within or below the chalk formation. All animals below are oviparous.

Chalk being so abundant in England, gave rise to the ancient name of that country, *Albion*, meaning whiteness or chalk. This substance covers one half of Europe.

It may have been ejected from the ancient deep by volcanic energy.

It is observed, that the remains of fish found in chalk, are of a roundish shape. This may arise from the circumstance, that the chalk surrounded the fish in a soft plastic state, like a pulp.

In the flint which accompanies chalk there are cavities containing animals. In the original formation, the flint was probably in a state of chemical solution, and coming in contact with organized matter deposited itself around it. In this series are found the Sea hedgehog, and the teeth of sharks of such a size as to justify the conclusion that the animal to which they belonged was *fifty eight feet in length.*

LECTURE X.

Of the Tertiary Formation.

The name tertiary, has been given to all the strata that are more recent than the secondary; it is called by De la Beche, *supercretaceous*, but these strata may cover any of the lower rocks, and in some parts of France they rest on granite, the name therefore is appropriate when applied to designate the upper strata.

The term tertiary is applied to the formations which comprise all the regular strata of limestone, marl, clay and sandstone, that have been deposited after chalk.

This numerical arrangement has been made but about twenty years. The term first began to be used at Paris and its environs; as in the excavation in and around that city, many new geological facts had been developed. A long period of time must have elapsed, after the chalk was formed, before the tertiary rocks came upon it. There are excavations in the form of basins, made in the chalk beds which are filled with the tertiary.

It is widely spread over many parts of the globe and often of considerable thickness.

Many of the tertiary beds contain the bones of the higher order of animals, as perfect in their organization as any of the existing species of quadrupeds.

It presents likewise frequent alternations of beds, containing the remains of marine animals; with other beds that contain exclusively the remains of land animals; and plants, and fresh water shells; hence the latter beds were denominated fresh *water formations.*

The fresh water formations are discoverable in some of the older strata, but they are not so distinctly marked as in the tertiary.

In some parts of this continent the line of separation between the tertiary and secondary is not conspicuous, or very faintly so.

The tertiary strata form the outer crust of the globe, and have every where, been subjected to erosion from torrents and inundations, or floods that have swept over parts of its surface, and transported the substances into distant countries, or into the ocean. It is impossible, from the present localities of the upper strata, to determine, with any precision, the boundaries of the inland lakes or seas in which they were deposited. Many of these strata have, evidently, once extended far beyond their present limits; but have been so completely destroyed, that we can infer their former existence, only from a few remaining detached portions.

France, more than scarcely any other District, affords an excellent example of the different strata. And has been studied with ardor and success by

the celebrated Cuvier and Brongniart. Which has tended to elucidate many facts, and afforded to Geologists data on which to found their systems.

Many of the tertiary beds in the Paris basins are not found elsewhere, and therefore cannot in all cases be taken as types of other tertiary formations; and the lower bed called *Plastic clay* is but very imperfectly developed near Paris.

In attempting to generallize the tertiary formations a difficulty presents itself, if we are to class them by their zoological characters; for some of the formations, which in certain situations, contain, exclusively the remains of marine animals, present, in other places, river, or lake shells, with wood, and the remains of land animals. It is, therefore, probable that while the waters in one Lake were saline, those in another might be fresh; and two contemporaneons formations may hence contain very different organic remains.

Plastic clay and marly clay with sand may be considered as one formation, of which in England and France the plastic clay is the lowest, resting on chalk. In the plastic clay, there are imperfect beds of wood coal (lignite); but in this and London clay the remains of marine animals are chiefly prevalent; though intermixed with some fresh water shells. The beds of sand are of considerable thickness. The bones of vertebrated animals of the higher order next to man, and the teeth of elephants are found in this formation.

In some places, the London, or marl clay is from one hundred to four hundred feet thick.

This clay appears to be the limit of the Saurian tribe.

The bones of a species of crocodile have been found in this clay. Ammonites and Belemnites and many genera of testaceous animals which have left their remains in chalk, appear to have been extinct before the deposition of the clay.

Nautilites have been found in the clay, similar to those now inhabiting the Indian ocean. The shells belong mostly to genera inhabiting our present seas, though of different species.

The water arising from springs in this formation generally, contains sulphate and muriate of lime, magnesia and iron.

This formation contains the remains of the narrow toothed Mastodon, and of other mammalia.

In France, a coarse limestone called *calcaire grossier*, is deposited on the plastic clay. It is a yellowish earthy limestone, not Oolite. It alternates with argillaceous marl and shale, and with calcareous marl. It is found to be one hundred and twelve feet in thickness.

In this are found the fossil *nummulite*, so named on account of its being flat and round, resembling money, or small coin. It also contains numerous porous shells, and the bones of the Walrus.

Thin strata of flint, or chert are often found in this formation.

Siliceous limestone also occurs in small quantities.

Gypsum alternates with argillaceous beds and calcareous marl. Although gypsum occurs lower down.

The gypsum beds are covered in Paris by marine sand and sandstone. The sandstone is often composed of transparent pure silex, and contains occasionally small scales of mica. This is called the *upper marine formation.*

The marine sand and sandstone are sometimes covered with a bed of argillaceous and frruginеous marl in which are imbedded layers of hornstone, full of holes or cavities, which forms the *burrh* stone, used as millstones. When unmixed they are pure silex. Color reddish or yellow; containing no shells or organic remains.

In the tertiary formation, we first come to the remains of *viviparous* animals, or those which produce their young alive; which fact shows that land had now been provided for them. These animals, of which there are several hundreds, are now extinct. They lived at a time when the region in the vicinity consisted of low marshes, islands and lakes.

This petrifaction of animals is not peculiar to the epoch when the rock formations were effected but takes place at the present day, in seas, springs, and lakes.

Upper Fresh water Formation, so called, because the shells found in it are analogous to those of fresh water. It consists of calcareous and siliceous earth, pebbles worn by attrition, marly clay, sand, gravel, and *debris.*

The tertiary formations have been deposited from materials diffused, or dissolvd in water, in independant basins and at various epochs. The remains of dicotyledonous plants, fresh water

shells mixed with the remains of sharks, alcyonia, crabs and marine shells, seem to indicate that these strata were deposited in estuaries which were occasionally inundated by fresh water.

During the period in which these strata were deposited, violent convulsions succeeded by long intervals of repose, took place; by which some of the mountains on the globe were elevated, and portions of those formations elevated with them; so as now to cap their summits.

The tertiary formations are distinguished from diluvium and alluvium by a much finer state of most of the materials that compose them, by the greater regularity of their stratification, and by their containing peculiar organic remains.

Diluvium includes that coating of gravel, sand and loam which is spread over almost every part of the surface of the globe, and which has been obviously mingled confusedly together by powerful currents of water.

This has been refered by some to the agency of a general deluge; but probably there were several deluges, partial or general, concerned in bringing about the present state of the surface of our globe. Others regard diluvium as the result of various agencies, operating at different periods; among which are the floods produced by the elevation of the rock strata at several times. But they do not admit that we have in this diluvium *any evidence of a deluge contemporaneous with that described by Moses.* They do not *deny* the occurrence of the Noacan deluge, they merely say, that Geology does not furnish sufficient evidence

of such a catastrophe, although it affords no evidence to the contrary, but rather a presumption in its favor, in the fact so abundantly proved by the records of Geology, that numerous deluges have occurred since the creation.

The *transient* deluge of Moses could not have produced all the diluvium which is now spread over the surface of this continent. This idea cannot be entertained on scientific principles, and is utterly repugnant to common sense and common observation.

Alluvium, this contains debris of rocks, sand, gravel, clay &c., together with decomposed animals and vegetables carried by, and deposited from water. The causes are daily operating, and unlike the other formations, it is forming in many places every year.

The most common is that produced by the overflowing of rivers, and it forms the most valuable agricultural district.

Coast Alluvium is that produced by tides and currents of the ocean, which frequently transport large quantities of soil from one place to another.

Salt marsh Alluvium, results from the joint action of two and sometimes three causes. 1. The decay of salt marsh plants. 2. The *silt* brought over the marsh by tides. 3. From the alluvial soils brought down by streams.

Peat, or the deposite on the bottoms of ponds, lakes and estuaries, various equatic plants take root, and by their decay increase the deposite. At length the pulpy mass nearly reaches the surface, sphagnus and other mosses take root in it,

with numerous other plants, and by their gradual decomposition the pond or lake becomes converted, in process of time, into a swamp or marsh; the lower part of this marsh will be found to be converted into perfect compact peat, with alternate layers of mud, the next stratum will be less compact, and the upper will be interlaced fibres and roots with very little earth.

In the vicinity of limestone, marl is found in alluvium composed of lime and fine clay.

Alluvium of disintegration, is that formed by the wearing away of rocks by water and attrition.

Many rocks are liable to disentegration, such as sandstone, gneiss, some species of greywacke, Mica and talcose slate &c.

Alluvium of degradation, is that which arises from the wearing down of mountains and hills, and is the deposite of valleys, occasioned by rains, frosts and gravity.

That mountains are lessening in height appears evident from observation, and as a proof that the surface of the globe has not existed in its present state eternally, as some would unphilosophically imagine, but as it was *successively* formed, so it is *successively* wearing away.

LECTURE XI.

On Volcanoes.

Volcanoes are openings made in the earth's surface by internal fires. From these are regularly, or at intervals, ejected smoke, vapor, flame, large stones and sand, or melted stones called lava.

Some throw out mud and water.

There are between two and three hundred active volcanoes now on the globe.

They are most frequently situated near the sea, or in the vicinity of large lakes, and they break out from unfathomable depths below the surface of the ocean, and form islands.

When a volcano breaks out in a new situation, it is preceded by violent earthquakes, rumbling subterranean noises, the ground is heated and swelled up, at length a rent, or fissure is made sometimes of vast extent.

Through this opening, masses of rock with flame, smoke and lava are thrown out, choke up part of the passage, and confine the eruption to one aperture or more, around which conical hills or mountains are formed.

The concavity in the centre is called the crater.

The following are the prognostics of an eruption from a dormant volcano.

1. An increase of smoke from the summit, which sometimes rises to a great height. 2. Tremendous explosions like the firing of artillery, which are succeeded by red colored flames, and showers of stones. 3. Ejection of lava from the top of the crater, or through the sides of the mountain. This has been known to continue several months.

The lava in time becomes consolidated, forming a stony mass often not less than some hundred square miles in extent.

After the lava ceases to flow, intensely black clouds, composed of a dark sand or powder, improperly called *ashes*, are thrown out of the crater, and sometimes, at noon day, involve the country in total darkness. Toward the conclusion, the color of the volcanic ashes changes to white, this is *pumice* in a finely comminuted state.

When the lava flows freely, the earthquakes are less frequent and violent, which affords a proof that they were occasioned by the confinement of the erupted matter both gaseous and solid.

The seat of the volcano is not in the mountain itself, this is merely a chimney or vent for the gaseous and solid fluid. For in some eruptions the matter ejected exceeds in solid contents the mountain itself; and this during several eruptions, yet the mountain remains stationary neither do its sides fall in; a proof that the fire is not in the mountain.

Kircher informs us, that up to the year 1660, the ejections from Ætna would equal a mass twenty times as large as the mountain itself. In 1775, the same volcano poured out another stream of lava twelve miles in length, one mile and a half in breadth, and two hundred feet high.

Submarine volcanoes are preceded by a violent boiling and agitation of the water, and by the discharge of volumes of gas and vapour, which take fire and roll in sheets of flame over the surface of the water. Masses of rock are darted with great violence through the water, and accumulate until they form islands. Sometimes during an eruption the crater rises out of the sea.

Some volcanoes throw out aqueous torrents, mixed with sand and stones. The volcanoes in S. America oftener throw out these substances, than lava. And some, according to Humbolt, have thrown out *small fish*, which resembled those in the lake near the mountain.

Volcanoes frequently occur in groups, sometimes arranged along a line, as if formed over a vast chasm.

In South America, they are arranged in rows sometimes in one line, and sometimes in two parallel lines; generally in the same direction as those of the Cordilleras, and sometimes they form an angle with it of 70 deg.

The volcanoes of Mexico form a narrow zone, between lat. 18 deg. 59 min. and 19 deg. 12. min. This is regarded as a vast chasm 750 miles in length extending from the Atlantic to the Pacific.

There appears to be a connection between volcanoes at a vast distance from each other.

It is highly probable from the remains of ancient volcanoes, that their action was much more intense than at present.

The only formations of hard crystalline rocks, in the present day, are volcanic; and if we trace the connection which exists between modern and ancient volcanic rocks, and between the latter and the rocks of trap and porphyry among the ancient rock formations, we shall extend the influence of volcanic fire over a great portion of the globe.

Pseudo Volcanoes. This name has been given to those accidental combustions of beds of coal. There are instances of coal beds being on fire for many years. Some of the coal beds near Pittsburg, Pa. have been on fire for upwards of forty years, and are continually emitting smoke from their summits. The beds of clay associated with the coal is converted into a substance resembling Jasper.

The sulphuret of iron and carbonaceous matter contained in the clay and other minerals associated with the coal, decompose rapidly when moistened with water. During the decomposition sufficient heat is evolved to ignite the bituminous matter in the coal, and when once ignited, it will burn for a long period.

The earth itself is, in all probability, the great laboratory, in which by the aid of subterranean heat, are combined and prepared the mineral substances that compose the hard crystalline crust of the globe.

All the minerals which compose primary rocks

occur in a perfect state in modern or ancient volcanoes.

The substances ejected from volcanoes belong to the four grand divisions of the mineral kingdom, the inflammable, saline, metallic and earthy.

The inflammable substances are sulphur, carbon and hydrogen.

Sulphur combined with oxygen forms sulphurous and sulphuric acid.

Carbon combined with hydrogen forms bitumen, and carburetted hydrogen gas.

The Saline products are alum, sulphate of iron and copper, sulphate of magnesia, gypsum, muriate of Ammonia, muriate of Soda, muriate of Copper, muriate of Iron and muriatic acid.

The metallic substances, are iron, titanium, antimony, copper, manganese, tellurium, Gold. Iron in different combinations, occurs in the fissures of many volcanoes; also specular oxide of iron.

The earthy products are either vitreous, or stony, scoriaceous, or spongy, or in loose grains, or powder.

Volcanic rocks are chiefly composed of feldspar and the dark colored mineral called augite. Contents; hornblende, magnetic iron ore, olivine, mica, leucite, iron pyrites, garnets, rubies, and zircon.

The white or grey lava is composed principally of feldspar, to which the French have given the name *Trachyte*; the common or stony has a white or greyish color, fracture dull and more or less fine grained. Lustre glistening, when compact,

it is called *pearl stone*. It melts readily, into a grey ishglass. *Pumice* appears to be formed from trachyte by an intense heat.

Obsidian, or volcanic glass so nearly resembles lumps of black glass that it can scarcely be distinguished by an unpractised observer. Color, velvet black; thin pieces translucent. Harder than glass and strikes fire with steel.

Basalt, is a volcanic product, colors greyish black, brownish grey, or bluish black; occurs in amorphous masses, or in globular, columnar, or tabular forms; fracture splintery, or coarse grained, uneven; sometimes conchoidal, lustre feebly glimmering, or dull; streak, ash grey; often porous, or vesicular. It is often porphyritic, containing imbedded crystals of hornblende, olivine, feldspar, quartz, mica, analcime, clay &c.

Columnar basalt, occurs in columns of a prismatic form, having from three to nine plane sides, most commonly five, or six. These columns are of all sizes from a few inches to several feet in diameter, and sometimes nearly 100 feet high, occasionally straight, but often curved; they are jointed, or composed of several pieces of the same shape and dimensions, lying one on the other, the end of one being convex and the other concave, so as to fit each other like a ball and socket.

Various theories have been adopted for the explanation of volcanic phenomena, none of which are perfectly satisfactory: the real causes appear to be subjects of conjecture. We are familiar with some of the effects; though with the districts most ravaged by the erupted matter, we are far

from being well acquainted; our principle knowledge of volcanoes being derived from the two largest active vents of Europe, Ætna and Vesuvius, but principally from the latter. Ætna covers a considerable surface, but Vesuvius sinks into insignificance, when compared with some of the great volcanoes of the world.

From their general proximity to, or occurrence in the sea, it has been supposed that the active state of volcanoes has been produced by the percolation of sea-water to certain metallic bases of the earth's or alkalies at various depths beneath the surface, which metallic bases being thus inflamed, cause the phenomena observed in volcanic eruptions. The volcanoes in the interior of Mexico and in Tartary, have been accounted for, by the advocates of this theory; the former, by supposing a connexion between the vents of Calima, Jorullo, Pococatepetl and Orizaba, all situated in the same line; the latter, by considering the waters of salt lakes may percolate to their foci. As the first chemical operation, if this theory was true, would be the union of the oxygen with the metallic bases, and the escape of an immense quantity of hydrogen, M. Gay Lussac has objected to it, that pure hydrogen is not evolved from volcanoes; because, if it were present, it would be inflamed by the red hot matter ejected from the crater. Dr. Daubeny, on the other hand, supposes the hydrogen to have combined in its *nascent* state with sulphur, and the two bodies to have been evolved in the form of sulphuretted hydrogen gas. He also considers that the

presence of a large quantity of muriatic acid would destroy the inflammability of the hydrogen.

According to the same author, the gasses evolved from volcanoes consist of muriatic acid gas, sulphur combined with oxygen, or hydrogen, carbonic acid gas and nitrogen; and a quantity of aqueous vapor.

A large portion of the globe is volcanic, or is the effect of volcanic agency. The whole of Iceland may be considered little less than a volcanic mass, in which there are many apertures for the ejection of lava, ashes and other products. The igneous matter struggles to escape in various places, and consequently, many single eruptions from different points have taken place since the records of history. There have been twenty-two eruptions from Hecla since 1004; seven from Kattlagian Jokul since 900; and four from Krabla since 1724.

In Iceland, the eruptions are not confined to the immediate dry land, but have pierced through the sea in the vicinity. In January, 1783, a volcanic eruption, described as flame, rose through the sea; several islands were observed, as if raised from beneath, and a reef of rocks exists where these appearances were observed. According to Sir George Mackenzie, the flames lasted several months, during which, vast quantities of pumice were washed on shore. In the beginning of June, earthquakes shook the whole of Iceland; the flames in the sea disappeared; and the dreadful eruption commenced from the Shaptar Jakul, which is nearly two hundred miles dis-

tant from the spot where the marine eruption took place.

Another marine eruption occurred near the same island, in June 13, 1830; an island was formed and consequent eruptions were apprehended in the interior.

There are numerous islands composed entirely of volcanic matter in different oceans, many of them are now on *arches of fire;* and in some, active volcanoes still exist. The dome or cone not giving way before the pressure of water, but gradually accumulating a mass of lava, cinders and ashes, so that the islands have become firm, and even of considerable size. Owyhee, or Hawaii, is perhaps a magnificent example of such an island. The whole mass, estimated as exposing a surface of four thousand square miles, is composed of lava, or other volcanic matter, which rises in the peaks of Mouna Rou and Mouna Kaah, to the height of between fifteen thousand and sixteen thousand feet above the level of the sea. According to Mr. Ellis, the crater of Kiranea is situated in a lofty, elevated plain, bounded by a precipice fifteen or sixteen miles in circumference, apparently sunk from two to four hundred feet below its original level. "The surface of this plain was uneven, and strewed over with loose stones and volcanic rock; and in the centre of it was the great crater, at a distance of a mile and a half from the place where we were standing. We walked on to the north end of the ridge, where the precipice being less steep, a descent to the plain below seemed practicable. After

walking some distance over the sunken plain, which in several places sounded hollow under our feet, we, at length, came to the edge of the great crater, where a spectacle, sublime and even appalling, presented itself. Immediately before us yawned an immense gulf, in the form of a crescent, about two miles in length, from N. E. to S. W., nearly a mile in width, and apparently eight hundred feet deep. The bottom was covered with lava, and the southwest and northern parts of it were one vast flood of burning matter, in the state of ebullition, rolling too and fro its fiery surge, and flaming billows. Fifty-one conical islands of varied form and size, containing as many craters, rose either round the edge, or from the surface of the burning lake; twenty-two constantly emitted columns of grey smoke, or pyramids of brilliant flame; and several of these, at the same time vomited from their ignited mouths, streams of lava, which rolled in blazing torrents down their black indented sides into the mass below." From the existence of these cones, it was concluded, that the mass of boiling lava resulted from the streams poured from the craters into this upper reservoir, which appeared to vary in its level; for there were marks on the rocks bounding it, which indicated that the great crater had been recently filled up three or four hundred feet higher to a black ledge, whence there was a slope to the hot fluid mass."

The depth of water round Owhyhee, and indeed round the Sandwich Islands generally, is so great, that they are somewhat dangerous to ap-

proach in stormy weather, as anchorage cannot be obtained, except close to the land; which seems to demonstrate that these volcanic masses rise from considerable depths, and are only partly out of water.

The number of volcanoes which border the Pacific ocean or occur in it, or in that part of the Indian ocean in the vicinity of Java far exceeds that of any other part of the world. From Terra del Fuego they occur northerly through the range of the Andes, often attaining very considerable elevations. In Mexico, the northerly line is met by an east and west line, connecting it with the volcanoes in the West India Islands. In Calafornia there are three volcanoes of which one, Mt. Elias, is variously estimated from thirteen thousand to seventeen thousand feet in height. America is connected by means of volcanic vents of the Aleutian, or Fox Islands. From Kamptschatka southward, volcanoes are observed in the Kurule Islands, Japan, the Soo Choo Isles, Formosa and the Phillippines. From the latter, a range ol volcanic vents proceed to nearly latitude 10 deg., S. ranges westward along this parallel for about twenty-five degrees of longitude, and then turns up N. W diagonally through about twenty deg. of latitude, This line, which, when represented on maps, resembles an enormous fish hook, passes from the Phillipines by the N. E. point of Celebes, Gilolo, the volcanic isles between New Guinea and Timor, Floris, Sumbawa, Java and Sumatra, to Barren Island.

Active volcanoes are not so abundant in, or on

the shores of the Atlantic. In fact the shores of this ocean in Europe, Africa and America, appear free from them, at the present time; if we except Mexico, and the land connecting the main body of N. America with the Southern continent, which may be considered as common to the Atlantic and Pacific oceans. A volcano has been discovered off the main land of Greenland. It is situated in the island of Jan Magen, and presents marks of recent eruption. Its crater is about five hundred feet deep, and two thousand feet in diameter.

Teneriffe affords the greatest volcanic elevation in the Atlantic, the Peak rising two thousand two hundred and sixteen feet.

It is computed that there are twenty volcanic eruptions every year on the globe, of more or less activity.

There are eighty principal volcanic eminences connected with Ætna.

Many volcanoes are known to have been burning for a long period of time. Stromboli has been in a state of eruption for *two thousand years.*

Volcanoes appear to be among the instruments used by the Author of Nature for the production of the various mineral forms, found in the crust of the globe. As all fused substances will tend to crystallize, or arrange their component parts more compactly, where their liquidity continues the longest, and their loss of temperature is the slowest, we find that lava currents are always more crystalline, or compact in their interior parts; and that dykes cutting volcanic cones

are generally more compact and crystalline towards their interior parts than towards their walls or sides. It has been inferred from the appearance and distribution of the ejected matters, that many volcanic rocks have not been formed in the atmosphere, but beneath seas, and that they have been subsequently elevated. The ashes aud pumice ejected from volcanoes seem to be, merely the lighter substance floating on the surface of the great fused and incandescent mass within, produced by the action of elastic vapors, or by the intumescence of that matter under diminished pressure. The force required to eject such light substances, is evidently far inferior to that necesary for the propulsion of the more solid lava, consequently the one is more common than the other.

Volcanic substances vary from the lightest ashes to a highly crystalline rock, the intermediate states being vitreous and of the character of *obsidian.*

The quantity of minerals detected in volcanic products is very great, a circumstance by no means surprising, when we consider the various elementary substances acted upon by heat in the bowels of a volcano, and having a tendency to combine with each other in various ways.

The most abundant rock in New England which appears to have a connection with volcanoes is *trap*, or greenstone. This abounds throughout the Connecticut valley, in the states of Massachusetts and Connecticut. It presents what are called mural fronts, of regular slope, from the vertex

down to the ruins, which generally lie in large masses below the columns. The form of this rock is prismatic, and its cracking is vertical, so that the water enters into it, freezes, expands, and thus breaks down the walls. It is supposed to have been once melted, and therefore a production of internal fire.

There are marks of volcanic action in other parts of the U. States, besides the Connecticut valley. The trap rocks in the vicinity of Boston; in the State of New Hampshire; the Palisadoes on the Hudson, N. Y. and in some parts of the Green Mountains in Vermont, indicate volcanic influence at some remote period in the existence of our planet.

Psuedo Volcanoes have been frequent in some parts of our country, particularly in the vicinity of iron and copper mines. Probably occasioned by the decomposition of Pyrites.

LECTURE XII.

On Earthquakes.

Earthquakes and volcanoes may be considered as different effects, produced by the agency of subterranean fire. They frequently accompany each other, and in most instances the first eruption is preceded by an earthquake of greater or less extent. They are more frequent in volcanic districts than any other, though they are not peculiar to those districts.

PROGNOSTICS.

An uncommon agitation of the waters of the ocean and lakes; ejection of mud from springs, accompanied with a fetid odour. Air generally calm. Animals discover much alarm and appear to be instinctively aware of approaching calamity. A deep rumbling noise like carriages over a rough pavement, a rushing sound like wind, or a tremendous explosion like that of artillery, immediately precede the shock, which suddenly heaves the ground upwards, or tosses it from side to side with violent and successive vibrations.

One shock seldom lasts more than a minute, but is frequently succeeded by others of greater, or less violence, which for a considerable time continue to agitate the surface of the earth.

During these shocks, large chasms are frequently made in the earth, through which flame and smoke issue; these sometimes break out where no chasms can be perceived. Frequently stones and torrents of water are ejected from these openings. Cities have sunk down or been engulphed in those openings, and a stagnant lake has occupied the situation.

In some instances, the extent of the effects of earthquakes is very great. During the earthquake of Lisbon 1774, almost all the springs and lakes in Britain, and every part of Europe and some parts of the United States were violently agitated, and the waters of Lake Ontario, were violently troubled at the same time. Hence we conclude that there are subterranean communications under large portions of the globe, and that large quantities of elastic vapour are generated and endeavoring to escape. The gas appears to be hydrogen or sulphuretted hydrogen.

In some instances it may be steam which condensing would produce a vacuum, and cause the external air to press downwards.

It is highly probable that every extensive earthquake is succeeded by a volcanic eruption more or less distant.

The cause of earthquakes and volcanic eruptions is deeply seated below the surface of the earth. On the same day on which Lisbon was

nearly destroyed by an earthquake one fourth of the northern hemisphere felt the shock, including all Europe, a great part of northern Africa, the United States and West Indies. The bed of the Atlantic was raised above the surface of the ocean, in many places, and flames and vapour were discharged; this was observed by vessels at sea.

The cause which must produce a simultaneous concussion over such a vast extent, must probably be seated about midway between the surface, and centre of the earth.

Earthquakes in general are more severely felt in mountainous than in low countries.

All the phenomena that accompany earthquakes indicate the intense operation of elastic vapour, expanding and endeavoring to escape where the least resistance is presented, and producing vibrations of the solid strata.

The horrid crash like the rattling of carriages, which precedes earthquakes, may be occasioned by the rending of the rocks, or parting of the strata through which the confined vapour is forcing a passage.

If there be a central fire under every part of the globe, or if certain spaces only are filled with igneous matter, we can scarcely doubt that chemical changes are continually going on, which will also change the electrical relations between mineral beds. A series of strata may act like the plates of an immense voltaic battery, and discharge the electricity from one part of the globe to another, creating vibrations that may agitate a whole hemisphere. Subterranean thunder is

often heard in the district of the Andes and the Himmelah mountains which are followed by earthquakes.

Earthquakes and volcanoes appear to be the great agents employed by the Author of Nature, to bring about the present condition of our planet for the convenience and sustenance of man, to elevate new and submerge ancient continents, and to renovate the surface of the globe, every where. And as these changes are universal, they must have happened ages ago before the creation of man; for it would have been impossible, constituted as man is, for him to have existed during the phenomenon.

Although it can be demonstrated that the world is not eternal, yet a long period must have elapsed before man could have existed, constituted as he now is; therefore. we infer, that the six days of creation must have been periods of indefinite duration, notwithstanding we acknowledge the Mosaic account to be correct, viz. "In the beginning, God created the heavens and the earth," and established laws for the government thereof, under His direction. For to suppose a law, would be to suppose a law-giver, and an executor, otherwise, the law is a nullity. Matter cannot contain in itself a law and an executor. Inert matter can have no *design*, or motive.

LECTURE XIII.

The Sea amd the Atmosphere.

The ocean and the atmosphere have undoubtedly both contributed to produce changes in the surface of the globe.

Nearly three fourths of the surface of the globe is assigned to the water.

Although the land rises considerably above the level of the sea, yet in reality it is but slightly removed above the level, when considered as it should be in reference to the radius of the earth.

The superfices of the Pacific ocean alone, is estimated at somewhat greater than that of the whole dry land.

Dry land can only be considered as so much of the rough surface of our globe as may happen for the time being to be above the water, beneath which it may disappear as it has done at various times.

The mean depth of the ocean has been variously estimated at between two and three miles.

The mean height of the dry land above the ocean level does not exceed two miles.

Therefore, assuming two miles for the mean depth of the ocean, the water occupying three fourths of the earth's surface, the present dry land might be distributed over the bottom of the ocean, in such a manner that the globe might present a mass of water. With this at command, every variety of the superficial distribution of land and water may be imagined, consequently every variety of organic life, each suited to the various situations and climates under which it would be placed.

Masses of salt water are sometimes included in the dry land, which have been called Caspians, from the Caspian sea, the largest body of internal salt water. These have no visible communication with the ocean.

No measurement by soundings has exceeded one mile and a quarter.

The ocean has not always occupied its present bed, for rocks almost entirely composed of the shells or remains of marine animals are found in almost every country that has been explored; and on the summits of high mountains, some of which rise more than two miles above the level of the sea.

The whole body of the ocean is composed of salt water, which does not vary materially in composition.

The gravity and pressure of the sea are of great consequence in accounting for many geological phenomena; for as the pressure increases with the depth, effects, which would be possible at one depth, would be impossible at another. Thus,

from experiment, it is found, that carbonate of lime may be fused by heat, without the loss of its carbonic acid, if subjected to great pressure, snch as exists at the bottom of the deep ocean.

The compressibility of water is found to be 51. 3, millionths of its volume for a pressure equal to one atmosphere, it follows then, that at great depths and beneath a great pressure of the ocean, a given quantity of water will occupy less space than on the surface, and will consequently by this, circumstance alone, have its specific gravity greatly increased.

In former periods, the waters of the ocean covered the summits of some of the highest mountains; we are thus irresistibly compelled to admit, either that the sea has retired and sunk far below its former level, or that some power operating from beneath has lifted up the islands and continents, with their hills and mountains, to their present elevation above the ocean.

The atmosphere which surrounds the earth and is at the height of at least forty five miles, does not concern the Geologist so much as the Natural philosopher, in his investigations, except as an agent in wearing down the solid surface of moderate elevations, as well as rocks, hills and mountains, by the precipitation of rain, and by change of temperature. The wearing down of mountains by rain, and decomposition of the mineral substances by exposure to the atmosphere, afford frequent opportunities for observing that the mineral substances of which they are composed are of different kinds.

The atmosphere has undoubtedly undergone great changes since the creation. The revolutions and changes to which the earth was subjected in the first epochs of creation might have been designed to prepare the atmosphere by nicely balancing its two constituents, oxygen and nitrogen, so as to render it fit for the free and salutary respiration of animals.

If the globe was an ignited fluid mass, in the beginning, then all the aqueous particles that form the ocean, and all the more volatile mineral substances would have existed in the form of vapour, and would have constituted a dense, or nebulous medium of vast extent, similar to the atmosphere of a comet. By refrigeration, the volatile mineral matter would become concrete, and the aqueous particles precipitated, until the constitution of the atmosphere became fitted for the support of animal life. And it is probable, that the animals of the earliest creation were constituted to breathe a denser atmosphere than the present one. Such an atmosphere would, in a considerable degree, equalize the mean temperature of the earth, and the excess of moisture and carbonic acid gas, would also be favorable to the rapid developement of vegetable organization.

The earth has evidently been gradually cooling for ages; some have supposed that the time would arrive when it would be actually and universally *frozen*, that is, when it ceases to radiate heat. This supposition is unchemical, for it can radiate no longer than until there is an equilibrium between the atmosphere and the interior of the

earth. This equilibrium may be restored without effecting very materially the present temperature of the surface.

LECTURE XIV.

On the Formation of Soils.

Soil, on which vegetation of different kinds flourishes, is formed by the decomposition of the harder strata, and of animal and vegetable substances occasionally mixed with it.

A due proportion of the different ingredients is requisite to the fertility of the soil.

The disintegration of mountains and the filling up of valleys are designed by the great Author of Nature, for the support of the vegetable tribes, and these, in their turn, for the support of animals, who, in their turn, shall administer to the support of man.

The quality of the soil depends on the nature of the rocks from which it is formed; those rocks

which decompose the most readily form the most fertile soils.

Granite and siliceous rocks form sandy soils. Argillaceous rocks form stiff clay soils, and calcareous rocks, when mixed, with clay form marl, but when not covered by other strata, they form a transient but nutritious soil.

For a productive soil, the due intermixture of the three earths, lime, sand and clay is necessary. The oxide of iron appears also requisite.

Different vegetables require different admixtures of earth. They require it, first, because it is necessary for their growth that the soil should be sufficiently stiff and deep to keep them firm in their places; secondly, that it should not be too stiff to prohibit the expansion and growth of their roots; and, lastly, that it should supply them with a constant quantity of water, in due proportions.

By imitating nature, by observing the soils in which uncultivated plants grow luxuriantly, we may obtain advantageous results, and acquire certain fixed principles to guide us in our attempts to bring barren soils into a state of profitable cultivation.

When rocks contain silex, clay and lime, they form soils whose fertility may be considered permanent.

The small portion of earths and alkalies which plants contain, are, in all probability, formed from a process of vegetation, from more simple elements as the earths and alkalies are compound substances.

The principal elements found in plants are, hydrogen, carbon and oxygen. Hydrogen and oxygen exist in the proportion to form water. By volume 2, hydrogen 1, oxygen; by weight, 88. 9, oxygen, 11. 1, hydrogen nearly.

Water and the atmosphere contain in themselves, or in solution, all the elements for the support and growth of vegetables. But most soils are either too wet, or too dry, too loose, or too adhesive, to admit plants to extract these elements, in the proportions necessary to their growth.

Manures, by furnishing in great abundance the Hydrogen, Carbon and Nitrogen, which plants require, supply the deficiency.

In proportion as soils possess a due degree of tenacity, and power of retaining and absorbing heat and moisture, the necessity for a supply of manure is diminished; and in some instances the earths are so combined as to render the application of manure unnecessary.

In general the character of a soil depends more upon the nature and amount of vegetable and animal matter it contains, than upon the nature of its other ingredients.

Alluvial meadows have always been celebrated for their fertility, because they are a deposite from water, of the finest and richest portion of every soil over which the waters have passed.

Diluvium is the most unfriendly to fertility, and requires abundant manuring.

New red sand stone is easily disintegrated, and affords a good soil for some kind of vegetables,

especially that part denominated *red marl*; this forms an excellent soil for wheat, rye, barley, beans, &c. It is also peculiarly well adapted for fruit.

Argillaceous slate and greywacke afford by decomposition a black, or dark colored soil, this though cold, is capable of being made very fertile and is peculiarly well adapted for onions and many other garden vegetables.

Oxide of iron when not in too great proportion, when mixed with other ingredients, affords a productive soil.

Limestone, when decomposed, affords a good soil.

Talcose and Mica slate do not afford a productive soil by decomposition.

Gneiss affords a strong productive soil, especially when the rock contains iron.

Greenstone by decomposition affords a fertile soil, probably, in a great measure, owing to the iron.

Granite and Sienite afford a superior soil, it is generally strong and retentive of moisture. It is usually of a dark color and fine texture.

Lime is the only earth, either carbonate or sulphate, that has been generally used to mix with soils.

It is considered by agriculturists in general, as a manure, but its operation as such is very imperfectly understood. Burnt lime, when caustic, destroys undecomposed vegetable matter, and reduces it to mould; so far its use is intelligible. It combines, also, with vegetable and mineral

acids in the soil which might be injurious to vegetation; here its operation is likewise intelligible; but if we assert, that when burnt lime has absorded carbonic acid and becomes mild, it gives out its carbon again to roots of plants, we assume a fact, which we have neither experiments nor analogies to support. The utility of lime in decomposing vegetable matter and neutralizing acids is obvious, but its other uses are not so obvious; except we admit that it acts mechanically on the soil, and renders the clay, or sand with which it is intermixed, better adapted to the proper expansion of the roots, and more disposed to modify the power of retaining, or absorbing the requisite degree of heat and moisture, which particular ingredients may demand.

The temperature requisite for the growth of plants is influenced by the power of different soils to absorb and retain heat from the solar rays, which depends much upon the moisture and tenacity of the soil. Rich or clayey soils absorb heat slowly, and part with it again more reluctantly than the calcareous soils, owing to the greater quantity of moisture in the clay, which is an imperfect conductor of heat. Hence the vegetation of grasses in the spring is much sooner on limestone and sandy soils, if not extremely barren, than on clayey, or deep rich soils; and the difference is more than reversed in the autumn.

It is important that every person intending to purchase a farm, should understand the Geological formations in and around it. In this way, only, he can form a correct judgment of the produc-

tiveness of the soil; and save much expense and disappointment, to which those who are ignorant of the principles of Geology are continually liable. He can ascertain pretty accurately, the quantity of labor and money that will be necessary to be expended to bring his farm into successful cultivation, and the vegetables that are peculiarly adapted to the soil, which will yield a luxuriant produce.

LECTURE XV.

Of Organic Remains.

Organic remains are those remains of animals or vegetables found imbedded in strata of different ages. In general they differ from animals and vegetables now existing.

They are generally colored by the strata in which they are imbedded.

Some animal remains contain the most delicate fibres perfect and unbroken, which seems to prove that the mineral matter in which they are depos-

ited was in a finely comminuted state, in a tranquil sea. In some instances, the most delicate shells are regularly arranged, so that their genera are readily determined. While in others, they are broken and confused. These facts are of immense geological importance, as they mark in a striking manner, the convulsions which the globe has undergone at different periods.

Some of the more delicately constructed animals, and even fish whose bodies are found entire, imbedded in stone, appear to have been instantaneously destroyed and enveloped in the mineral matter before the putrefactive process had commenced. The petrifaction must, in some instances, immediately have commenced after death.

All animals are distributed according to their organization, into four grand divisions: *Vertebrated, Moluscous, Articulated and Radiated.*

1. *Vertebrated*, having a skull containing the brain, and a spine or back bone, containing the principal trunk of the nervous system, commonly called the spinal marrow. This division comprises the *Mammalia*, or such as suckle their young, and birds, reptiles, and fishes; the latter are called oviparous animals, such as produce their young from an egg. *Viviparous*, bring forth their young alive.

2. *Moluscous*, animals which have no internal skeleton, the muscles are attached to the skin, which, in many species, is covered with a shell. The nervous system and viscera are composed of detached masses, united by nervous filaments, they possess only the sense of feeling, taste and

sight, but some want the latter. They have a complete system of circulation, and particular organs for respiration. Animals with bivalve, univalve and chambered shells, are of this division, such as oysters, muscles, nautulus, &c.; some are destitute of a shell.

3. *Articulated.* In this division are comprehended crustaceous animals and insects; their nervous system consists of two long chords, ranging along the body, and swelling out in different parts into ganglions and knots. Worms, having their bodies composed of rings are called *annelides;* they have red blood; some species inhabit a calcareous tube, supposed to be formed by exudation.

4. *Radiated*, the animals which were formerly called zoophytes, or animal plants, as the corallines which were long mistaken for marine vegetables. The organ of sense and motion are disposed circularly, around a centre, or axis; destitute of nervous system, circulation obscure. Many have no power of locomotion, as madrepores and encrinites, others as *echinus*, possess a very complex organization, and the power of moving from place to place on their spines, which serve as feet.

The radiated animals have left their remains disposed in the transition strata; and they afford us the most ancient history of animated nature; they are likewise found in some of the upper series of limestone.

The pentacrinus makes its first distinct appearance in the lias.

Articulated animals, some of the annelides inhabiting tubes are found in the upper secondary and tertiary strata, crustaceous animals, crabs &c., are found in the upper secondary and tertiary strata; they are more common in chalk and in beds of clay covering chalk. The Trilobite is found in slate, and may be considered as one of the oldest inhabitants of the globe, cotemporaneous with radiated animals. It had three longitudinal lobes, with transverse fins, something like those under the tail of a lobster. The genus is supposed to be extinct.

Articulated animals have supplied the smallest number of organic remains.

Moluscous animals. Bivalve shells occur in transition limestone, but rarely; some chambered shells are also found in transition limestone; bivalves and univalves are abundant in the lower secondary series. Also chambered shells, such as nautilites and ammonites abound in the secondary and chalk formation; but no ammonites are found in the strata above chalk.

Top shaped spiral univalve shells first appear in the lower secondary series, but become more numerous in the upper.

In the tertiary strata, the species of univalve shells greatly exceed the bivalve. The organic remains of shells in the tertiary strata bear a nearer resemblance to moluscous animals living in our present seas, than those found in more ancient strata.

Vertebrated Animals, are arranged under four classes. Fishes, reptiles, birds and mammiferous

animals. Remains of fishes are rare in transition rocks; but are found in abundance in the lower secondary strata. In some instances the entire bodies are well preserved, also the bones, scales, palates and vertebræ are found in the upper secondary and tertiary strata.

In the lower secondary are found entire skeletons of animals belonging to the Saurian or lizard tribe, and are very abundant in an argillaceous limestone called lias, and in the beds of clay that are over it. Many of these are different from any known genera now existing, and were inhabitants of the ocean, being furnished with paddles instead of feet, such as the Ichthyosaurus and Plesiosaurus. Other saurian animals having feet, allied to the present genera of lizards and crocodiles, they were evidently amphibious; these are found between the lias and chalk. The Iguanodon is found in this series; it was of the Saurian tribe and gigantic size, being eighty feet in length; and the thickness of the body equaling that of the elephant. It is supposed to have been herbivorous.

The remains of birds are rare in any of the strata.

Animals of the Mammalia class occur in the tertiary strata, and in beds of gravel and clay. Cetaceous animals allied to the Whale and Seal, occasionally occur in the tertiary strata. The bones of mammiferous land quadrupeds occur in the upper part of the tertiary strata; they are more frequently found in beds of clay and gravel. Seventy different species of land quadrupeds ac-

cording to Cuvier, have been found in the tertiary strata near Paris. Nearly forty of these are of species no longer existing, and several belong to extinct genera.

Neither the bones of man or monkeys have been found with those of the more ancient inhabitants of the globe.

The animal remains found in transition are almost exclusively marine, hence we could not have inferred that any portion of the globe was dry land, when these deposites were made. In some of the slate rocks however, a few remains of terrestial plants nearly allied to ferns are found, which indicate the existence of some tracts of dry land, or islands at that remote period.

As we ascend from the lower to the upper strata, a progression from imperfect to more perfect forms of vegetables, is evident. In transition slate are found algæ, or sea weed, and a few fronds or leaves of ferns.

Coal measures abound in vegetable remains. As Ferns, Equisetæ, Lycopodiæ, Palms and canes or reeds.

In the secondary class are found an higher species of ferns and Lycopodiæ, and the Coniferæ and Cycodeæ.

In the tertiary beds are found plants of an higher order still, which are rarely if ever found in the secondary veins, such as the perfect plants, trees, &c.

It appears that the devastating effects accompanying the vast changes which this planet has undergone, were so extensive, that not only some

species of quadrupeds were entirely removed, of some genera, such as the elephant, rhinoceros and hippopotamus, of which other species still remain; but that other *genera*, such as *Mastodon*, Palæotherium and Anoplotherium were completely annihilated.

These changes in the state of the plants, and this partial destruction of quadrupeds, appear to have been succeeded by the creation of man, and of such quadrupeds and other animals as were fit inhabitants of the earth after its last change. But man did not retain his dominion uninterrupted long. The scriptures teach us that a flood of waters was brought upon the earth which prevailed on it for an hundred and fifty days, and by which the whole race was nearly destroyed. The Mosaic account of this deluge has, however, been doubted, from the total absence of the fossil remains of man. But a reference will shew, that no circumstances are stated in that account which will authorize the supposition, that the deluge was accompanied with such subversive violence, as would bury its victims in those situations which would dispose to the mineralization and consequent preservation of their remains.

The assumption of successive creations with accordant changes in the state of the earth, does not agree *literally*, with the Mosaic account of creation, as commonly received. The *facts*, however, appear to be as they are stated, and cannot be controverted on philosophical and geological principles. They are in perfect accordance with the laws of nature, which have ever been under

the guidance of Infinite Wisdom. It must, therefore be, that we have misinterpreted, or misunderstood the sacred history. Or, may not the *days* of creation be considered as epochs of indefinite duration? As the Hebrew word for day is often so translated in the Scriptures.

This system of successive creations fitted to the existing state of the planet, appears not only not to derogate from the wisdom and power of the Almighty, but to be perfectly in accordance with the agency of Providence, as taught by the Author of our religion. The world is seen in its formation and continuance, constantly under the providence of Almighty God, without whose knowledge, not a sparrow falls to the ground.

Under these impressions we view the results of these several changes and creations, as manifesting the prescience, power and benevolence of our Great Creator. The general form of the earth's surface, varied by the distribution of hills and valleys, and of land and water; the prodigious accumulation of coal derived from vegetables of a former creation, and the accompanying slates and schists; the useful, durable and often beautiful, encrinitical and shelly limestones; the immense formations of chalk and flints, and the various series of clays; all evince a careful providence in the wants of man. The several *breaks* and *faults* in the stratified masses, and the various inclinations of the different strata, as well as the vast abruptions by which these various substances are brought to the hand of man, may be regarded as most beneficent provisions resulting from ca-

tastrophes too vast and tremendous for human intellect to comprehend.

From these several creations, it appears that beings have proceeded, gradually increasing in superiority from testaceous animals to reptiles, fish, marine and fresh water animals, quadrupeds, and lastly, man, who, in his turn, is destined, with the earth he inhabits, to pass away, and be succeeded by a *new heaven and a new earth.*

H.

Hading, dipping of a metallic vein.

Helix, shells of the snail family, terrestrial and aquatic.

Hone, whetstone slate.

Hornblende Rock, composed mostly of hornblende.

Hornstone, principally composed of silex and alumine.

Hyaline, transparent like glass.

I & J.

Jasper, a very compact, hard stone, composed mostly of alumine, colored by iron.

Ichthyosaurus, a fossil animal having a head like a Dolphin, of the Saurian genus.

Jet, a substance found with coal of the newest formation, and sometimes with lignite and amber. It is principally carbon.

Iguanodon, a fossil herbivorous reptile. It is considered by Cuvier, the most remarkable animal yet discovered. It was, in a living state, between sixty and seventy feet in length.

Imbedded Rock, a bed of any rock in a slate mountain, or in any other stratum, where the stratum is different from the rock enclosed.

Incandescence, in the state of a red heat.

Inclination of Strata the raised situation of strata from a horizontal position.

Intermediate Rocks, transition rocks.

Intumescence, swelling, puffed up.

Inundations, overflowing of Seas or Rivers.

Isocronous, in the same time.

Isothermal Lines, lines of equal temperature.

K.

Kaolin, soft earthy feldspar used for porcelain.

L.

Lamella, a thin layer, or scale.

Lamellar Structure, slaty, or in layers.

Lava, a volcanic product mostly composed of feldspar.

Lenticular, in the form of a lens.

Leucite, a volcanic product composed of silex, alumine and potash.

Lias, argillaceous limestone. Water setting lime.

Lignite, wood coal.

Lime, one of the earths; its metallic base is calcium.

Limestone, a stone composed of carbonic acid and lime.

Line of Bearing, a line drawn lengthwise of the strata.

Line of Dip, a line drawn from the outcrop of the strata down to the horizon.

Lydian Stone, Touch stone. Basanite.

M.

Madrepores, stony polypi, with concentric lamellæ in the form of Stars; in a living state, the stony matter is covered with a skin of living gelatinous matter, fringed with little bunches of tentaculæ; these are the polypi; the skin and the polypi contract on the slightest touch. Madrepores are sometimes united and sometimes detached; where the laminæ take a serpentine direction, they are called *Meandrina*, or brain stone.

Madreporites, stony madrepores.

Magnesia, one of the earths, abounds in steatite and gives to the rock a soapy feel, and the property of resisting high degrees of temperature.

Magnesian Limestone, Dolo-

mite, a limestone containing magnesia, some specimens used for water lime.

Mammillary or Mammiferous, covered with roundish protuberances.

Manganese, one of the metals, found in the state of an oxide.

Marine, relating to the ocean.

Marl, a composition of calcareous earth and clay.

Marly Clay, London clay.

Mastoden, the Mammoth, according to Cuvier, it did not exceed the elephant in height, but was rather longer in proportion, its limbs rather thicker and its belly smaller. It appears to have had a trunk, and to have agreed with the elephant in having tusks; and in the whole of its osteology except the teeth; which differ so much in every respect, as to forbid their being placed in the same genus.

Megalosaurus,, an enormous fossil lizard, in some instances, the animal must have attained the length of forty feet, and to have been eight feet high.

Mica, Isinglass, Muscovy glass.

Millstone grit, a sandstone containing angular grains of quartz.

Molasse, soft tertiary sandstone.

Moluscous, a term applied to soft animals having no bones, as the oyster and clam.

Monitor, a large fossil animal belonging to the Saurian genus.

Morains, piles of stones transported by glaciers.

Mountain Limestone, upper transition limestone.

Muschel kalk, a series of calcareous strata between the red sand stone and red marl, in France and Germany.

Muscle-bind, a stratum containing fresh water muscles.

N.

Nacre, like pearl.

Nacrite, a mineral resembling pearls.

Nagil-flue, a term used in Switzerland for sandstone conglomerate.

Norfolk-crag, the most recent of the tertiary beds in England.

O.

Obsidian, volcanic glass, resembling green bottle glass.

Oolite, a calcareous rock, composed of globules resembling the roe of fish, the upper of the secondary strata.

Orbicular, globular.

Organic, a term applied to animal, or vegetable remains.

Osseous, relating to bone.

P.

Pachydermata, thick skinned animals.

Partings, separation of strata.

Pebbles, stones rounded by attrition.

Pepperino, volcanic tufa.

Petrifactions, where stone has taken the place and form of organic remains.

Phonolite, Clinkstone.

Pitchstone, semivitreous stone of a blackish green, or nearly black color, of volcanic origin.

Plaster stone, gypsum.

Plastic clay, clay of which bricks, and pottery are made.

Plesiosaurus, from the Greek *plesios*, approximate to, *Sauros*, a lizard, a fossil animal of the Saurian family, distinguished by its peculiar dentition and the number of vertebræ in the back.

Plumbago, graphite, black lead, carburet of iron.

Porphyritic Structure, containing large crystals of feldspar.

Porphyry, composed principally of feldspar.

Potstone, a greenish mineral composed principally of silex, magnesia, iron and alumine; less uncteous than steatite.

Pozzolana, a volcanic substance, consisting of minute particles of scoriæ which have been partially decomposed.

Primary Rocks, those supposed to have been formed before animals or vegetables.

Protogene, a variety of granite in which talc or chlorite supplies the place of mica.

Protrusion, applied to rocks, which have been ejected through others by some force below.

Psammite, a species of Greywacke.

Pudding Stone, rounded stones cemented by a mineral paste.

Pumice, lighter colored lava, considered to be decomposed feldspar.

Purbeck Limestone, an argillaceous limestone.

Pyriform, pear shaped.

Pyrites, sulphuret of iron, or copper.

Pyritous Shale, third Greywacke of Eaton.

Q.

Quadrate, somewhat square.

Quartz, one of the simple minerals, composed mostly of silex.

Quartz Rock, a rock composed of crystalline grains of quartz.

Quaternary, the more recent tertiary strata.

R.

Radiated Animals, Zoophytes, the lowest order of animals, sometimes called animal plants, such as the corallines, encrini, madrepores, &c. which were long mistaken for marine vegetables.

Radiated Structure, applied to those minerals whose fibres are broad, flattish and diverging.

Rents, the partings or divisions of rocks.

Retinasphaltum, a resinous substance found in Bovey coal.

Rock Salt, salt obtained in a stony form from mines.

Roe Stone, Oolite.

Rubble, composed of fragments, or loose materials.

S.

Saddle Shaped, applied to strata that dip in opposite directions.

Sandstone, a term applied to a stone composed of grains of sand or gravel, and oxide of iron.

Sapphire, crystallized alumine, or clay.

Saurian, a term applied to the genus *lizard*.

Saussurite, crystallised Serpentine, combined with feldspar, or Jade.

Scaglia, a formation of chalk.

Schistose, slaty.

Seams, partings.

Secondary Formation, that immediately above the transition.

Selenite, crystallized gypsum.

Septaria, stones divided into cells or partitions, sometimes the cells are empty and sometimes filled.

Septæ, partitions.

Setæ, bristles, or hairs.

Shale, slate with an excess of carbon.

Shell marl, marl containing shells.

Sienite, a variety of granite in which hornblende supplies the place of mica.

Silex, one of the earths, and the most abundant; it is a constituent of most rocks.

Sill, synonymous with stratum.

Silt, the deposite from salt water.

Sinus, an excavation.

Siphunculus, a tube passing through the chambers of some univalve shells.

Slate, argillite, and other schistose rocks.

Slate Clay, shale charged with carbon.

Slaty, composed of straight parallel thin plates, lamellar.

Stalactites, carbonate of lime formed by the percolation of water charged with carbonate of lime, through the roof of caverns to which the stalactites are appended.

Stalagmites, substances arising from the floors of caverns, occasioned by the dropping of lime water from the roof.

Stratum, pl. ***Strata***, continuous beds of rocks.

Stratified Rocks, those rocks which lie in regular strata.

Striæ, thread like lines.

Sub, (in composition) means approaching to, or nearly.

Submarine, under the ocean.

Submersion, sunken.

Subterranean, under the earth.

Succession, a term applied to the regularly placed strata.

Sulcus, a groove, or furrow.

Supercretaceous, a term improperly given to the tertiary strata.
Superposition, is when similar beds occur together in the same order.
Swilleys, small coal basins.
Swine Stone, Bituminous limestone.

T.

Tabular, in large plates.
Talc a substance resembling mica, but not elastic.
Talcous slate, slate containing a large portion of talc: saponaceous and sectile, nearly allied to chlorite slate.
Tertiary Formation, the upper formation.
Testaceous, shelly.
Thermal waters, warm springs.
Tortuous, twisted, winding.
Tow, combustible clay in coal mines.
Trachyte, white, or grey lava, composed principally of feldspar.
Transition Formation, that next to the primitive, sometimes called intermediate.
Trap Rock, greenstone, the principal constituent hornblende.
Traumate, greywacke.
Trilobite, a crustaceous fossil animal.
Troubles, broken strata in coal fields.
Truncated, cut off.

U.

Unconformable position, those rocks not in the order of superposition.
Univalve, shells containing one valve.
Upheaving, forcing up from beneath.

V.

Veins, foreign minerals passing through a stratum.
Vertebrated, animals, those animals possessed of a skull and spine.
Vesicular, containing cells or holes.
Volcanic Rocks, those formed by the action of volcanoes.

W.

Wacke, earthy basalt.
Way boards, strata of clay which divide the strata of limestone.
Whetstone, a variety of talcy slate with quartz.
Whinstone, a variety of trap.
Whitestone, a variety of granite in which feldspar is the principal ingredient, by some called *Eurite*.
Wild measures, soft imperfect limestone and shale.
Wood coal, lignite.

Z.

Zetchstein, magnesian limestone.